2 F

THE INSTITUTION

OF

MECHANICAL ENGINEERS.

ESTABLISHED 1847.

PROCEEDINGS.

1902.

PARTS 3–5.

PUBLISHED BY THE INSTITUTION,
STOREY'S GATE, ST. JAMES'S PARK, WESTMINSTER, S.W.

CONTENTS.

1902.

PARTS 3-5.

PAST-PRESIDENTS.

George Stephenson, 1847–48. *(Deceased* 1848.)

Robert Stephenson, F.R.S., 1849–53. *(Deceased* 1859.)

Sir William Fairbairn, Bart., LL.D., F.R.S., 1854–55. *(Deceased* 1874.)

Sir Joseph Whitworth, Bart., D.C.L., LL.D., F.R.S., 1856–57, 1866. *(Deceased* 1887.)

John Penn, F.R.S., 1858–59, 1867–68. *(Deceased* 1878.)

James Kennedy, 1860. *(Deceased* 1886.)

The Right Hon. Lord Armstrong, C.B., D.C.L., LL.D., F.R.S., 1861–62, 1869. *(Deceased* 1900.)

Robert Napier, 1863–65. *(Deceased* 1876.)

John Ramsbottom, 1870–71. *(Deceased* 1897.)

Sir William Siemens, D.C.L., LL.D., F.R.S., 1872–73. *(Deceased* 1883.)

Sir Frederick J. Bramwell, Bart., D.C.L., LL.D., F.R.S., 1874–75.

Thomas Hawksley, F.R.S., 1876–77. *(Deceased* 1893.)

John Robinson, 1878–79. *(Deceased* 1902.)

Edward A. Cowper, 1880–81. *(Deceased* 1893.)

Percy G. B. Westmacott, 1882–83.

Sir Lowthian Bell, Bart., LL.D., F.R.S., 1884.

Jeremiah Head, 1885–86. *(Deceased* 1899.)

Sir Edward H. Carbutt, Bart., 1887–88.

Charles Cochrane, 1889. *(Deceased* 1898.)

Joseph Tomlinson, 1890–91. *(Deceased* 1894.)

Sir William Anderson, K.C.B., D.C.L., F.R.S., 1892–93. *(Deceased* 1898.)

Professor Alexander B. W. Kennedy, LL.D., F.R.S., 1894–95.

E. Windsor Richards, 1896–97.

Samuel Waite Johnson, 1898.

Sir William H. White, K.C.B., LL.D., D.Sc., F.R.S., 1899–1900.

The Institution of Mechanical Engineers.

OFFICERS.

1902.

PRESIDENT.

WILLIAM H. MAW, ... London.

PAST-PRESIDENTS.

SIR LOWTHIAN BELL, BART., LL.D., F.R.S., ... Northallerton.
SIR FREDERICK J. BRAMWELL, BART., D.C.L., LL.D., F.R.S., London.
SIR EDWARD H. CARBUTT, BART., ... London.
SAMUEL WAITE JOHNSON, ... Derby.
PROFESSOR ALEXANDER B. W. KENNEDY, LL.D., F.R.S., .. London.
E. WINDSOR RICHARDS, ... Caerleon.
PERCY G. B. WESTMACOTT, ... Ascot.
SIR WILLIAM H. WHITE, K.C.B., LL.D., D.Sc., F.R.S., .. London.

VICE-PRESIDENTS.

JOHN A. F. ASPINALL, ... Manchester.
ARTHUR KEEN, ... Birmingham
EDWARD P. MARTIN, ... Dowlais.
T. HURRY RICHES, ... Cardiff.
A. TANNETT-WALKER, ... Leeds.
J. HARTLEY WICKSTEED, ... Leeds.

MEMBERS OF COUNCIL.

SIR BENJAMIN BAKER, K.C.B., K.C.M.G., LL.D., D.Sc., F.R.S., ... London.
SIR J. WOLFE BARRY, K.C.B., LL.D., F.R.S., ... London.
HENRY CHAPMAN, ... London.
HENRY DAVEY, ... London.
WILLIAM DEAN, ... Folkestone.
EDWARD B. ELLINGTON, ... London.
H. GRAHAM HARRIS, ... London.
HENRY A. IVATT, ... Doncaster.
HENRY LEA, ... Birmingham.
SIR WILLIAM T. LEWIS, BART., ... Aberdare.
JAMES MANSERGH, F.R.S., ... London.
HENRY D. MARSHALL, ... Gainsborough.
THE RIGHT HON. WILLIAM J. PIRRIE, LL.D., ... Belfast.
SAMUEL R. PLATT (deceased September 1902), ... Oldham.
SIR THOMAS RICHARDSON, ... Hartlepool.
JOHN F. ROBINSON, ... Glasgow.
MARK H. ROBINSON, ... Rugby.
JOHN W. SPENCER, ... Newcastle-on-Tyne.
SIR JOHN I. THORNYCROFT, LL.D., F.R.S., ... London.
JOHN TWEEDY, ... Newcastle-on-Tyne.
HENRY H. WEST, ... Liverpool.

HON. TREASURER.

HARRY LEE MILLAR.

AUDITOR.

ROBERT A. MCLEAN, F.C.A.

SECRETARY.

EDGAR WORTHINGTON,

The Institution of Mechanical Engineers,

Storey's Gate, St. James's Park, Westminster, S.W.

Telegraphic address:—*Mech, London.* Telephone:—*Westminster,* 264

The Institution of Mechanical Engineers.

PROCEEDINGS.

July 1902.

The Summer Meeting of the Institution was held in Newcastle-upon-Tyne, commencing on Tuesday, 29th July 1902, at Ten o'clock a.m.; William H. Maw, Esq., President, in the chair.

The President, Council, and Members were received in the Rooms of the Literary and Philosophical Society by the Right Worshipful the Mayor of Newcastle-upon-Tyne, Alderman Henry William Newton, and by the Members of the Reception Committee.

The Mayor of Newcastle said it afforded him very great pleasure to welcome the Institution of Mechanical Engineers to the City of Newcastle, and he believed it was the third occasion on which Tyneside had been so honoured. The visit of the Institution should be of advantage to the district, and also to the gentlemen taking part in the Meeting, inasmuch as they had the opportunity of meeting their confrères, and by the attrition of controversy arriving at the truth. It was impossible to conceive a district in this country more fitly adapted for such a congress than the district surrounding Newcastle. The great George Stephenson, whose name was a household word, was the pioneer of the engineering profession, and the fact had to be recognised that mechanical engineering was the lever which must move the world onward. It underlay every branch of industry, and nothing of importance could be accomplished without the assistance of the mechanical engineer. It permeated science in all its ramifications, and was frequently the motive force

(The Mayor of Newcastle.)

by which progress was made. Iron shipbuilding was one of the industries first conceived and adopted on the Tyneside, and he could remember, as a small boy, seeing the first iron ship launched from the yards at Howden by Mr. John Coutts, who was succeeded by Mr. Charles Mitchell, of great shipbuilding reputation. There were also the great works at Jarrow of Palmer, a name which was honoured in the North, and he felt sure that but for advancing age Sir Charles would have been present at the meeting, taking a lively interest in a work with which he had been identified for more than half a century. Electricity had found its exponent in Tyneside in the person of Mr. Swan, the fellow worker of Edison. The continuity of history had been carried into modern times. First there was the Hon. C. A. Parsons, a name which was identified with progress. Although not a Tyneside man, Mr. Parsons served his apprenticeship under Sir William Armstrong, and was one of the distinguished engineers which that firm had equipped for the work of life. The great works of Elswick required no reference, as the Members would have an opportunity of seeing them for themselves. Those works were associated with a name which was honoured and admired by all. Lord Armstrong had done much for Newcastle. It might be thought by the Members that his Worship's views arose rather from the pride of one who was born in the district, and to counteract any such feeling his Worship quoted the following remark by Mr. Gladstone, when he inspected the district as far back as 1864. Mr. Gladstone then said: "I know not where to seek, even in this busy country, a spot or district in which we perceive so extraordinary or multifarious a combination of the various great branches of mining, manufacturing, trading, and shipbuilding industry, and I doubt whether the like can be shown, not only within the limits of this land, but upon the whole surface of the globe." In 1864 that statement was absolutely correct, but in 1902 it had become intensified. The export of the Tyne had been duplicated, and the population of Newcastle had been vastly increased, for Newcastle now claimed to be the centre of a population of a million souls. While Newcastle had increased in this direction, the industries, although in many respects suffering change, had been

able to rise to the occasion, and today, as in 1864, Newcastle occupied a pre-eminent position in the mechanical industries and enterprises of this country. He had great pleasure, in the name of the Corporation, and on behalf of the City, in extending to the Members a most hearty and cordial welcome. He hoped that the visit would be pleasant to the Members individually and profitable to the Institution. His duty terminated in asking the distinguished President of the Institution, who represented both the literary and practical sides of mechanical engineering, to take the chair. In Mr. Maw he was sure the Members had a gentleman eminently capable of representing the profession, and he had much pleasure in vacating the chair in favour of so distinguished a gentleman.

The President thanked the Mayor and the Reception Committee for the exceedingly cordial welcome which the Institution had received. He pointed out that it was really the fourth time the Institution had met in Newcastle. Forty-four years ago a Meeting was held in that city, while other meetings were held in 1859 and 1881, and on each occasion the meetings had been most successful. Their having been so was due to the very cordial co-operation of friends in Newcastle, not only to the owners of works which had been so freely thrown open to the Members, but also to the numerous gentlemen who aided in many ways in perfecting those details of arrangements which make or mar the success of such gatherings. On the present occasion the pleasant experience of the past had been fully repeated. The Institution had met in Newcastle—and in the towns which were being visited in the district—with the most cordial co-operation, and the most sincere endeavours to show the Members that they were most heartily welcome visitors. There would, he hoped, be an opportunity at the dinner that evening to refer in greater detail to the various kindnesses received, and he would therefore say nothing further now, except to repeat on behalf of the Members their most sincere thanks for the cordial way in which they had been received, and for the honour done to the Institution by the Mayor of Newcastle attending that morning to open the proceedings.

The PRESIDENT said he had the painful duty of referring to the loss which the Institution had sustained since the last gathering by the death of a Past-President, Mr. John Robinson. Mr. Robinson was elected a Member of the Institution in 1859, and at the time of his death had been a member for 43 years. He was elected to the Council in 1866, and from that time onward served the Institution most loyally in every way. He was President in 1878–79, and those who took part in the visit to Paris in 1878 would have a most vivid recollection of the admirable manner in which he conducted the proceedings on that occasion. It was an occasion which made very special demands on the President, and very few men could have carried out the duties so ably as Mr. Robinson did. At the Meeting of the Council on 17th July, a resolution was passed authorising a letter to be sent to Mrs. Robinson expressing the sincere regret of the Members of the Council at the great loss which she and her family had sustained, and also expressing their recognition of the valuable services which Mr. Robinson had rendered to the Institution. The President was sure that the members would endorse the Council's action in the matter.

The resolution was agreed to.

The Minutes of the previous Meeting having been read and confirmed, the PRESIDENT announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following one hundred and twenty-six candidates were found to be duly elected:—

MEMBERS.

ADAMS, JOHN HENRY,	Stoke-on-Trent.
ANDERSON, HARRY,	Greenhithe.
ARMES, BENJAMIN STEPHEN,	Sierra Leone.
ASTBURY, ALBERT JAMES,	Birmingham.
BAIN, DAVID,	Derby.
BOARDMAN, JAMES,	Moscow.

Bollinckx, Arthur, ...	Brussels.
Brown, James Clifford, . . .	London.
Dame, John Malvern, ...	Karachi.
Elphinstone, George Keith Buller, .	London.
Fletcher, William, ...	Newcastle-on-Tyne.
Forrest, Peter, ...	London.
Garratt, Herbert William, . . .	Lagos.
Graham, Charles Knott, . . .	Rochester.
Hill, Edmund Lewin, ...	Cardiff.
Orde, Edwin Lancelot, . . .	Newcastle-on-Tyne.
Ormsby, Edward Stuart, . . .	Rugby.
Riseley, Harry Lorimer, . . .	Wallsend-on-Tyne.
Robertson, David, ...	Selangor, Malay States.
Stevenson, Charles William, . .	Campinas, Brazil.
Vernon, Percy Venables, . . .	Coventry.
Walker, Edwin Robert, . . .	Wigan.
Watson, William Cummings, . . .	Newcastle-on-Tyne.
Way, Edward John, ...	Benoni, Transvaal.
Whitehead, Thomas Ross, . . .	Coventry.
Wollaston, Henry Uppleby, . .	Slough.

ASSOCIATE MEMBERS.

Ambler, Ratcliff Vincent, . . .	Iquique.
Amos, Harold Clyde, ...	London.
Anslow, David, ...	Wolverhampton.
Aspin, John, ...	Glasgow.
Ball, Comer Sandys, ...	St. Leonards-on-Sea.
Beaver, John Robert, ...	Valparaiso.
Berkeley, Tyrus Douglas, . . .	Wrexham.
Berrington, Ernest Evans Willoughby, .	London.
Bigg-Wither, Lionel, ...	Secunderabad.
Binns, Asa, ...	Chatham.
Blagden, Arthur Herbert, . . .	Shanghai.
Bowers, William Richard, . . .	Birmingham.
Boyd, Guy Westwood, ...	London.
Bridge, Arthur George, . . .	Rochdale.

Brown, James, ...	Longton, Staffs.
Browne, Benjamin Chapman, Jun., . .	Newcastle-on-Tyne.
Browne, William Ruddle, . . .	London.
Bunn, Charles William, . . .	West Bromwich.
Carwin, John William, . . .	Preston.
Chatterton, Richard, ...	Charlton, Kent.
Cowen, George Hepple, . . .	Sheffield.
Dabell, Alexander Frank, . . .	London.
Davis, Algernon Henry, . . .	Harrogate.
Deacon, Robert Dugald, . . .	Rio de Janeiro.
Espeut, Reginald William Armit, . .	Sierra Leone.
Fletcher, William Charles, . .	London.
Geach, Lewis Cecil, ...	London.
Goldie, Robert Murdoch, . . .	Singapore.
Greaves, Horace John, . . .	Leeds.
Haslam, Alfred Victor, . . .	Derby.
Hildreth, William Augustus, . .	Coventry.
Hislop, David Blaikie, . . .	Aberdeen.
Hislop, Laurence Robertson, . .	Paisley.
Hudson, Gerard, ...	London.
Hursthouse, Ernest William, . .	Perth, W. Australia.
Inder, Clarence John, ...	London.
James-Carrington, Henry, . . .	Birmingham.
Jameson, William Hope Masterton, .	Manchester.
Johnson, Philip Henry, . . .	Kroonstad, O.R. Colony.
Jones, Laurence Alban, . . .	Birmingham.
Kirton, Walter, ...	Pretoria.
Lawson, William, ...	Middlesbrough.
Liddell, Guy, ...	London.
Lyon, Arthur Anderson, . . .	London.
McMillan, John, ...	Edinburgh.
Meyrick-Jones, Leonard Meyrick, .	Cheltenham.
Mitchell, John, ...	London.
Montgomery, Charles Hubert, . .	Manchester.
Mowbray, Archibald Holme, . .	Glasgow.
Nelson, Robert, ...	Wallsend-on-Tyne.

Orr, John, ...	Kimberley, S. Africa.
Parker, Frederick Thomas, . . .	Morro Velho, Brazil.
Parkinson, Charles Frederick, . .	Paisley.
Paterson, William, ...	Alexandria.
Perry, Herbert Duncan Smith, . .	Manchester.
Phelps, George Ingram de Brissac, .	Birmingham.
Price, Albert Edward, . . .	Wolverhampton.
Ramsay, Andrew Cassels, . . .	Mex, Egypt.
Read, Charles Macartney, . . .	Malta.
Sheriff, John Edward, . . .	Lisbon.
Skinner, George, ...	Bolton.
Taylor, Ernest Edward, . . .	Leavesden, Herts.
Taylor, William Robert Cheetham, .	Oldham.
Thompson, Edgar Wakelin, . . .	Bombay.
Titren, Gerald Ernest de Keyser, .	Durban.
Warwick, Walter, ...	Bombay.
Watson, Herbert Edward, . . .	London.
Wetherell, Raymond Edward Cordeux, .	London.
Willis, George, ...	Eton.

ASSOCIATE.

Noyes, Edward, ...	Sydney.

GRADUATES.

Bate, Ernest Montagu, . . .	London.
Billinton, Percy Robert, . . .	Thornton Heath.
Bland, John William, ...	Bradford.
Camargo, John Antonio da Rocha, . .	London.
Chambers, Edward Haward, . . .	Tipton.
Chyn, ...	London.
Clark, Hubert Charles, . . .	Coventry.
Fawkes, Rupert Edward Francis, . .	Horwich.
Fox, Francis Henry Wright, . .	London.
Francis, Charles John Henry Watson, .	London.
Harrison, Nigel Sydney Augustine, .	Thornaby-on-Tees.
Hawkins, John Charles, . . .	Torquay.

Howell, Thomas Braithwaite, . .	Manchester.
Laird, Andrew Oswald, . . .	London.
Laird, Stanley Morrison, . . .	London.
Licence, Arthur Benjamin Cecil, . .	Bristol.
Maitland, Dascon James, . . .	Gainsborough.
Morgan, William Henry, . . .	Thornton Heath.
Pratchitt, William Monkhouse, . .	Carlisle.
Richards, Percy, ...	London.
Roberts, Edward Drayton, . . .	Glasgow.
Rosenthal, Frederick Michael Barbanel,	Northfleet.
Schultz, George Christopher, . .	London.
Sington, Leonard Francis Symons, .	Ashford, Kent.
Somers, Frank, ...	Birmingham.
Speakman, Edward Murray, . .	Glasgow.
Tchighianoff, Alexander, . . .	London.
Thompson, David John Hamilton, . .	West Hartlepool.
Twelvetrees, Richard Walter Rickard,	Epsom.
Wright, Arthur Reginald, . . .	London.

The President thought the members would be glad to know that this list included 126 new members of all classes, and that the elections during the year had amounted to 381.

The President announced that the following eleven Transferences had been made by the Council since the last Meeting:—

Associate Members to Members.

Atkinson, Robert Ernest, ...	Leicester.
Briggs, Herbert, ...	Johannesburg.
Forbes, George Chichester, ...	Negapatam.
Griffiths, William John, ...	London.
Jackson, Harry Loxton, ...	Bolton.

Larard, Charles Edward, ...	London.
Leitch, Archibald, ...	Glasgow.
Mindo, Arnold Waldemar, ...	Gloucester.
Pilling, Frederick Stott, ...	Devonport.
Richardson, John Robert, ...	Lincoln.

Associate to Member.

Cryer, Arthur, ...	Cardiff.

The following Papers were then read and discussed:—

"Liquid Fuel for Steamships"; by Mr. Edwin L. Orde, *Member*, of Newcastle-upon-Tyne.

"Pumping Plant for Condensing Water"; by Mr. Charles Hopkinson, *Member*, of Manchester.

"Newcastle and District Electric Lighting Co.'s Power Stations"; by Mr. W. D. Hunter, of Newcastle-upon-Tyne.

"Electric-Supply Power-Station at Neptune Bank, Newcastle-upon-Tyne"; by Mr. W. B. Woodhouse, *Associate Member*, of Wallsend-on-Tyne.

At a Quarter to One o'clock p.m. the Meeting was adjourned to the following morning.

The ADJOURNED MEETING was held in the Rooms of the Literary and Philosophical Society, Newcastle-upon-Tyne, on Wednesday, 30th July 1902, at Ten o'clock a.m.; WILLIAM H. MAW, Esq., President, in the chair.

The following Papers were read and discussed:—

"Some Experiments on Steam-Engine Economy"; by Professor R. L. WEIGHTON, of Newcastle-upon-Tyne.

"The Application of Cylindrical Steam Distributing Valves to Locomotives"; by Mr. WALTER M. SMITH, *Member*, of Gateshead.

"Mechanical Appliances in Mines (Coal Cutting and Drilling)"; by Mr. R. H. WAINFORD, *Member*, of Newcastle-upon-Tyne.

The PRESIDENT proposed the following Votes of Thanks, which were passed with applause:—

To the Right Worshipful the Mayor of Newcastle-upon-Tyne and the Reception Committee in that City, especially the Conveners, namely, The Mayor, Sir Andrew Noble, Bart., K.C.B., F.R.S., Sir Benjamin C. Browne, D.C.L., Sir W. Theodore Doxford, M.P., and Sir Thomas Richardson, and the Honorary Local Secretary, Mr. H. I. Brackenbury, for the welcome they have extended to the Members, and for their hospitality in entertaining the Members to Luncheon in the Old Assembly Rooms on Tuesday and also on Wednesday.

To the Reception Committees in Sunderland and in The Hartlepools for their hospitality in entertaining large numbers of Members in each of these great centres of industry.

To Messrs. Armstrong, Whitworth and Co., and to Messrs. John Spencer and Co., for their kindness in throwing open their Works to the visit of Members, and to the latter firm for entertaining a large number of Members to Luncheon.

To the Municipal Authorities and the Proprietors and Engineers of Works and Collieries on the Tyne, the Wear, and at the Hartlepools, for the arrangements they have kindly made to receive the Members at their respective establishments.

To the Tyne Commissioners for lending their steamer, "J. C. Stevenson," for conveying the Members down the Tyne to visit places of engineering interest on the River.

To Sir Andrew Noble, Bart., K.C.B., for his hospitality in inviting the Members with Ladies to a Conversazione at Jesmond Dene House and to Luncheon at Chillingham Castle.

To the Directors, the Engineer, and Officers of the Newcastle and Gateshead Water Co., for providing an excursion through the Rede Valley for Members and Ladies, and entertaining them at Luncheon at Catcleugh.

To Mr. W. A. Watson-Armstrong for entertaining the Members and Ladies to luncheon at Bamburgh Castle and also at Cragside.

To the Honorary Local Secretaries: Mr. H. I. Brackenbury, of Newcastle; Mr. H. H. Wake, Mr. W. H. Dugdale, and Dr. Haswell, of Sunderland; and Mr. J. R. Fothergill, of West Hartlepool, for the admirable arrangements they have made for the convenience and enjoyment of the Members.

The Meeting then terminated at One o'clock. The attendance was 299 Members and 62 Visitors.

LIQUID FUEL FOR STEAMSHIPS.

By Mr. EDWIN L. ORDE, *Member*, of Newcastle-upon-Tyne.

The subject of this Paper is one which has already received so much attention that it is difficult today to contribute anything which possesses much value. A close examination of the literature which has appeared on the subject, however, seems to show that, from some cause or another, the many undoubted advantages which it offers have either not been fully appreciated, or if appreciated not pursued with sufficient determination to ensure that they shall be realised in actual practice. The explanation of this would appear to be that, until comparatively lately, liquid fuel was not obtainable in such quantities as are required to make it commercially useful.

For many years the Caspian Sea was the only place where liquid fuel was used in the furnaces of marine boilers, and as the quantity available was not sufficient to allow of its export, it could only obtain a very limited application. Of late years, however, the sources of supply have largely increased in number, and now that the large oil-fields of Borneo and Texas are in active operation, and commercial enterprise only needs the stimulus of demand to organize distributing stations, the question of the adoption of liquid fuel on a large scale appears to need for its solution only the close attention of engineers. The principal sources of supply are the fields of Borneo, Burmah, the Caucasus, Texas, and California; but there appear to be indications that further supplies exist, and were the demand assured, would be explored and developed.

The subject seems to fall naturally into four divisions :—

1st. The characteristics and calorific value of the various forms of liquid fuel at present available.

2nd. The general conditions which govern its combustion in boiler furnaces.

3rd. The various types of apparatus which have been designed for utilizing liquid fuel, and

4th. The actual results which have been obtained.

Characteristics.—The composition of petroleum is in itself a study which demands special knowledge, and only the points which are of importance from the point of view of combustion need be considered in this Paper.

The composition of petroleum is exceedingly complex, but as some of the phenomena which present themselves in using it as fuel are purely chemical, some attention to its principal characteristics is essential to the proper consideration of the subject.

Petroleum consists of a number of hydrocarbons which occur in the following series :—

1. $C\,n\,H_2\,n + 2$	Methane.
2. $C\,n\,H_2\,n$	Olefine.
3. $C\,n\,H_2\,n - 2$	
4. $C\,n\,H_2\,n - 4$	
5. $C\,n\,H_2\,n - 6$	Benzene.
6. $C\,n\,H_2\,n - 8$	
7. $C\,n\,H_2\,n - 10$	
8. $C\,n\,H_2\,n - 12$.	

Of the eight series, the first, second and fifth are those which occur most frequently and in the largest proportions, and as of these three the first or Methane series is probably the most important, a short consideration of its characteristics will be sufficient for the purpose of this Paper.

The first four members of the series are gaseous (Methane, Ethane, Propane, and Butane), when in contact with air at ordinary

temperature. The liquid members begin with $n = 5$ and end with $n = 25$, with higher values of n the members are semi-solid (Paraffins). The boiling-point rises fairly regularly with the increasing values of n from $n = 9$ upwards (each additional carbon atom representing a rise of about 20° C.), as also does the specific gravity, although the increase is not so regular.

The crude petroleums as they come from the wells are usually refined by a process of distillation, and the products of the process may be roughly divided into three groups:—

1st.	Light oils	distilling over up to 150° C.
2nd.	Illuminating oils	„ „ „ „ 300° C.
3rd.	Residuum.	

The American light oils consist principally of the members C_5H_{12} to C_8H_{18}, and the illuminating oils C_7H_{16} to $C_{16}H_{34}$ of the Methane series. The residuum can be subjected to higher temperatures when it yields (a) heavy oils which produce lubricating oil and paraffins, and (b) carbon in the form of coke.

The members of the three groups are further subdivided into about twenty for trade purposes. The specific gravities of the three groups are approximately:—

Light oils	0·65 to 0·78
Illuminating oils . . .	0·78 to 0·86
Lubricating oils . . .	0·86 to 0·96

No further consideration of the refining of the crude oils would be necessary, were it not for two very distinct processes of distillation, both of which present phenomena which exert an important effect on the behaviour of liquid fuel, when treated in the burning apparatus. These are:—

1st. The "cracking" process.
2nd. The effect of steam on distillation.

The "cracking" process consists in distilling over the lighter oils at temperatures above those at which they would boil under normal conditions. This is effected either by allowing the

products of the distillation to condense and fall back into the contents of the still, or by distilling under pressure. The effect of the process is to decompose the heavier oils remaining in the still, and materially decrease their specific gravity. The oil resulting from this process becomes more homogeneous in its composition than before, but, if the temperature in the still reaches too high a point, solid carbon is deposited in the form of coke. These deposits of solid carbon, unless careful attention is paid both to the temperature to which the still is exposed and to its design, form a large proportion of the residuum after the lighter oils have been taken off; and continuous distillation on the "cracking" principle seems to be impossible owing to the rapid increase in quantity; but in the presence of steam, on the contrary, it appears to be possible to distil practically the whole of the crude product. One explanation of this phenomenon that has been given is that steam has the property of lowering the boiling points of the hydrocarbons with which it is brought in contact, and therefore allows them to volatilize at temperatures below those at which the cracking process sets in. Superheated steam is generally used, in order to attain the temperature required for distillation, which reaches 550–600° F. in many cases. Air does not possess this solvent property, nor is it so convenient a vehicle for the heat required in the process of distillation. This part of the subject has been dealt with at some length, as the process of presenting the liquid fuel in boiler furnaces in the most suitable conditions for combustion is in many respects an analogous one. Before complete combustion can take place, the fuel must pass from the liquid to the vapour form, and it is obvious that the most successful apparatus must be that which accomplishes this object with the smallest expenditure of heat. The fuel oils in general use are the crude oils of Borneo and Texas, and the residual oils of the Caucasus and Burmah. The ultimate analysis of these oils is given in Appendix I. (page 428).

It has been suggested by some of the early writers on the subject, that liquid fuel has a higher calorific value than solid fuel of the same chemical composition, from the fact that a certain

amount of heat has been rendered latent in passing it from the solid to the liquid form; and it has therefore been argued that heat values calculated on the basis of solid carbon are underestimated to the extent of this latent heat of liquefaction. Dr. Paul who investigated the subject very closely has suggested 6,000 B.Th.U. as the value of the heat thus lost, but as this is the value assigned by Rankine to the latent heat of the gasification of solid carbon, it would appear to be too high for the latent heat of its liquefaction. The determination of the heat value of petroleum by the Bomb Calorimeter does not show the existence of this latent heat, and Dr. Paul comes to the conclusion that it is not probable that petroleum, when used as fuel, can be made to evaporate more than about 16 lbs. of water from and at 212° F. This agrees with nearly all the well-authenticated results that are on record.

Taking Borneo oil as an example, some heat balance sheets that have been experimentally obtained are given in Appendix II (page 428).

The heat lost in radiation was measured at a separate trial; the amounts thus found were interpolated in the balance sheet, and found to agree very closely with the result found by difference in the usual way, in all cases but the second when the observed evaporation was undoubtedly too high. The observed evaporation results were 15·4, 15·95, 14·6, and 14·48 respectively. The difference between the first and second pairs of experiments is due to the presence of water in the oil. This exercises a very important function in the behaviour of the fuel, and is responsible for much of the difficulty that has attended its use. The actual reduction of the heat value of the fuel = 13·14 B.Th.U. per 1 per cent. water in addition to the loss of the oil which it replaces; for example, 1 lb. of oil mixed with 10 per cent. water evolves

$$
\begin{array}{lrl}
 & 18831 \times 0 \cdot 9 = 16947 \cdot 9 & \text{B.Th.U.} \\
\text{less} & 131 \cdot 4 & \text{,,} \\
\hline
 & = 16816 \cdot 5 & \text{,,}
\end{array}
$$

a difference of 1915·5 B.Th.U., or a loss in evaporative power of nearly 2 lbs. of water from and at 212° F.

Besides this actual loss of heat, the presence of water destroys the conditions necessary for perfect combustion, and this occurs and may cause considerable damage to boilers of the ordinary marine type, although the quantity is not sufficient to extinguish the flame. The first effect is naturally to reduce the temperature of the flames and thereby increase their length, thus moving the point of highest temperature further in to the furnace, which has the effect :—

1st. Of rendering a large portion of the furnace heating surface entirely useless;

2nd. Of raising the temperature in the combustion chambers to a point which may be hurtful to the material; and

3rd. Of causing the last stage of combustion to take place in the smoke-box and funnel.

The conditions that attend and the re-actions that take place in burning liquid fuel in boiler furnaces present a problem, which has apparently not received the attention which it deserves. Petroleum vapour depends entirely on temperature, and it is therefore almost impossible to collect samples when actually burning it in a furnace. It seems obvious that the first effect of the furnace heat on the petroleum spray is to liberate hydrocarbon vapours, and to ignite them on the outer surface of the jet. The ignition raises the temperature of the whole of the jet, and probably dissociates some at least of the hydrocarbon vapours into carbon monoxide and hydrogen. In what form the undissociated hydrocarbon vapours burn, it is difficult to conjecture, but the appearance of the flames suggests that acetylene is present. This might conceivably arise from the reaction $CH_4 + CO = H_2O + C_2H_2$. As the temperature of the flame rises, the hydrocarbons are probably all dissociated and burn as CO and H to CO_2 and H_2O without further change. When the conditions are satisfactory, the flames are opaque and dazzling white in colour for a distance of some six inches from the nozzle of the burner, become semi-transparent, and almost violet in colour at the middle of their length, and shade into red at the end. In burning oil which is mixed with water the combustion is incomplete, the violet colour never appears and the end of the flame is dark red

and fringed with smoke. In some cases, where water is present in comparatively small quantities, the end of the flame is white and presents the appearance of acetylene, which may arise from want of sufficient heat in the flame to decompose the hydrocarbons. This has been observed, when, although no smoke was formed and the air-supply was not more than 20 per cent. above what is chemically necessary for the fuel, the evaporative performance of the boiler was poor, which confirms the existence of a low furnace temperature.

Burners.—The " burners," which have been designed for admitting liquid fuel into boiler furnaces, numerous as they are, may be broadly divided into three distinct types. These are :—

1st. Mechanical spray in which the liquid fuel is forced under pressure through nozzles, made of such a form as to break it up into a fine spray and thus render it inflammable.

2nd. Spray burners, where the liquid fuel is held in suspension and driven into the furnace by means of a jet of steam and compressed air.

3rd. Vapour burners in which the liquid fuel is volatilized and the vapour admitted to the furnace.

So many of these burners have been designed by various inventors that it is impossible to describe more than one or two, which are typical of each of these three main divisions, without overstepping the limits of a Paper, and in making his selection the author has endeavoured as far as possible to treat of those that have stood the test of actual working at sea.

Of mechanical spray burners very few have achieved success. It is obviously very difficult to devise an apparatus which is capable of dividing into a fine spray a material so thick and viscous as fuel oil. The best known and most successful burners of this type are those of Messrs. Körting Brothers, Fig. 1, Plate 42. The oil is first heated to a temperature of 130° C. (266° F.) and then forced under a pressure of about 50 lbs. per square inch through nozzles, each of which has a small orifice at the apex controlled by a central spindle with an enlargement of spiral form, so arranged as to impart a vortex motion to the oil as it passes through, of sufficient intensity

to make it fly into spray by centrifugal force as soon as it issues from the nozzle.

Plate 44 shows the way in which these burners are generally arranged and the refractory lining to the furnace. Some such arrangement is necessary to maintain the temperature at a sufficiently high point to vaporise the fuel, and to prevent condensation of the flame before it has attained the temperature required to ensure complete combustion. Another burner of this type is that of Mr. Swensson of St. Petersburg, Fig. 2, Plate 42. Here the fuel passes through a minute orifice, and is divided into spray by striking against a cutter placed at a short distance from the orifice. An adaptation of the Körting burner is used by Messrs. Howden, who have supplied some installations to boilers fitted with their well-known system of forced draught, Plate 44.

The second type is by far the best known. Typical examples are:—The Holden burner, Fig. 3, Plate 42; the Rusden-Eeles burner, Fig. 4, Plate 43. Both these burners are designed to work with steam as the spraying medium, but in the Holden burner a current of air is induced by means of a ring of steam-jets outside the flame, which ensures a rapid ignition of the outer layer of the spray, and a central current of air is also induced by the action of the jet of steam and oil passing from the burner.

The Rusden-Eeles burner, Fig. 4, is so well known as not to require a detailed description; it allows of separate adjustment to the steam and oil-jets, and is in all respects a simple and workmanlike fitting.

Fig. 5, Plate 43, shows a burner designed by the author to vaporise as much as possible of the fuel, to prevent any possibility of cracking the oil, and at the same time to sweep out in the form of spray any of the heavier products which might remain undistilled. The burner is designed to work with highly superheated steam (preferably 600° F.). The velocity of the jet induces a current of heated air which ensures instant ignition of the outer layers of the flame and consequent increase of temperature over the whole of the jet.

Of vapour burners, pure and simple, the author only knows of one at the present time—the Dürr—Plate 45. There are two reservoirs for containing oil, etc., called by the inventor gasifiers (Vergäser). The smaller gasifier is heated by means of a fire, and as soon as the oil which it contains is sufficiently heated to give off vapour, this vapour is lighted and the flame serves to heat the large gasifier, the vapour from which is burnt in the furnace of the boiler to which it is fitted. As soon as this flame is well established, the temperature inside the outer casing covering the two gasifiers is sufficient to maintain the vaporising process.

Separators.—In addition to the actual burning apparatus, no installation can be considered complete without (*a*) some form of filter to cleanse the fuel oil of impurities, and (*b*) some arrangement for separating water. This last is by no means so simple as it would at first sight appear. The specific gravity of most fuel oils is about 0·92 to 0·96, so that separation by the action of gravity alone is an exceedingly lengthy process and practically never complete; but as the coefficient of expansion of fuel oil is considerably higher than that of water, the action may be greatly hastened by heating the contents of the tank; the combination of oil and water however is curiously intimate, and a careful experiment showed that at a temperature of 140° F. seven days elapsed before the water was completely separated. A large expenditure of heat is required if the contents of the fuel tanks are to be maintained at such a temperature, and it is obvious that, unless the separating process is complete and the water is all drained out of the tank before any of the fuel is drawn off for use in the burners, the lower layers, which are the first to flow, are formed of a concentrated intermixture of oil and water. One way out of this difficulty consists of a swing pipe supported at one end by a floating vessel. The orifice of the pipe is arranged at a suitable distance below the surface of the liquid fuel, and a coil of steam pipe is fitted so as to raise the temperature of the oil immediately surrounding the opening into the pipe; the fuel passes through the swing pipe on its way to the burners, and is to a great extent freed of water at a comparatively small heat expenditure, Plate 46.

It is impossible within the limits of a Paper to describe fully the various arrangements that have been designed for burning liquid fuel, and the author would refer those who wish to pursue the subject to the writings of M. Bertin. The actual results obtained by successful installations of burning apparatus on sea-going steamers are somewhat difficult to obtain, but owing to the courtesy of the Shell Transport and Trading Co., the Burmah Oil Co., and Messrs. Körting, the author has been enabled to give figures showing the actual consumption of liquid fuel in practice as exemplified by mechanical and steam spray-burners. It is obviously impossible to draw any exact comparisons between solid and liquid fuels without complete trials carried out in such a way as to show the actual boiler performance, and there are unfortunately no available data which allow of this being done properly from a scientific point of view. Commercially, however, the results have some value, and to make the comparison as useful as possible the corresponding consumption of coal as actually ascertained is given in four cases.

Name of Ship.	Type Burning Installation.	Consumption per I.H.P. per hour in lbs.	Corresponding Consumption of Coal.	Heating Surface.	I.H.P.
"C. F. Laiesz"	Körting	1·408	1·93	7560	2200
"Sithonia"	Howden	1 065	1·49	6924	2500
"Murex"	Rusden-Eeles	1 3? / *16 tons.	25 tons.	5202	—
"Syriam"	do.	1·32	—	2480	800
"Khodoung"	The author. Armstrong, Whitworth & Co.	1·08	1·67	2700	960

* The consumption in this case is given in tons per day. From Sir Fortescue-Flannery's Paper in the Transactions of the Institution of Naval Architects, 1902. No I.H.P. was given.

Differences in consumption in favour of liquid fuel as compared with coal are shown as follows:—

"C. F. Laiesz"	say 27 per cent.
"Sithonia"	28·6 "
"Murex"	36 "
"Khodoung"	35·5 "

All the vessels have triple-expansion engines of normal proportions, except the "Sithonia," in which quadruple expansion machinery is fitted, and from the coal consumption trial the amount of water required per I.H.P. must be considerably less than in the other vessels referred to.

From the figures given above, it is evident that with a well-designed apparatus it is possible by good management to realize in actual practice the full difference in calorific value between liquid and solid fuel, at rates of evaporation such as are usually obtained in the boilers of vessels of the mercantile marine. At the higher rates of evaporation, such as required in war vessels, the problem becomes more complex, but now that it is receiving the serious consideration of the Admiralty, there can be no doubt that a satisfactory solution of this most important question will be arrived at.

In presenting this Paper the author, while conscious of its many shortcomings, hopes that it may serve to initiate a discussion in which more light may be thrown on the delicate problems involved in the combustion of liquid fuel than has hitherto appeared.

The Paper is illustrated by Plates 42 to 46, and is accompanied by 2 Appendices.

APPENDIX I.

Fuel Oils.

	Carbon.	Hydrogen.	Oxygen, &c.
	per cent.	per cent.	per cent.
Borneo . . .	87·8	10·78	1·24
Texas . . .	85·66	11·03	3·31
Caucasus . .	84·94	13 96	1·25
Burmah . . .	86·4	12·1	1·5

The calorific values are :—

Borneo	18831 B.Th.U.
Texas	19242 „
Caucasus	18611 „
Burmah	18864 „

These values are determined by the calorimeter.

APPENDIX II.

Heat Balance Sheet of Borneo Oil.

	Units of evaporation.			
Loss due to Moisture. 1. $\dfrac{\frac{10{\cdot}78}{100} \times 9 \times (212 - t) + 966 + 0{\cdot}48(T - 212)}{966}$ (where t = *initial temperature of oil*, T = *temperature of escaping gases.*)	1·15	1·0	1·2	1·19
2. Losses due to heat carried off in escaping gases. $\dfrac{1 + A^1 \times T}{4000}$. ($A$ = *weight of air required for combustion (observed)*) .	1·46	1·6	2·3	2·21
3. Loss due to radiation (observed) . . .	1·3	1·4	1·3	1·38
4. Heat employed in evaporation . . .	15·4	15·4	14·5	14·6
Total heat value of oil . .	19·4	19·4	19·4	19·4

Discussion.

The President considered the Paper one of very great value, and there was no doubt, as the author said, that the question of the efficient consumption of liquid fuel was one of great and growing importance. He asked the members to accord to the author a hearty vote of thanks for the trouble he had taken in preparing the Paper.

Mr. N. N. Wadia said the author had omitted to point out the enormous saving in the freight accommodation that could be effected by using petroleum in steamers. A regular line of steamers had been started by the Shell Transport Company to Bombay, and from the figures that Messrs. Graham and Co., their agents, had shown him before he left Bombay, there was an actual saving in bunker space of over 33 per cent. by using petroleum, which could be utilized for cargo. Another point he would like the author to explain a little more fully was the result with regard to smoke, by burning petroleum as compared with coal. That was a problem which had been very much discussed in naval circles, and he was sure that anything which would reduce smoke, as petroleum should do, would be very soon adopted.

Mr. Edward P. Martin, Vice-President, noticed in the Table (page 426) a comparison of the consumption of oil per hour in lbs. with the consumption of coal, and desired to know what character of coal the oil had been compared with.

The President asked whether any member could give some facts as to the treatment of the oil for the separation of water? It was a point of considerable importance.

Mr. William Boyd said the subject was one which had interested his firm for many years, and he regretted that he had not had the opportunity of seeing the Paper before it was read, as it was difficult to make remarks on the spur of the moment. Any member who visited the Wallsend Slipway Co. on Wednesday might possibly

(Mr. William Boyd.)
have an opportunity of seeing Körting's burners at work on an experimental boiler, and the Company would be pleased to show the practical application of the burner to an ordinary marine boiler in use in the works. The burner with which his firm was principally connected was described in the Paper as the Rusden-Eeles burner, and the results obtained in a large number of Messrs. Samuel's steamers in the Shell Line with that burner had been very successful.

The only objection found in practice to that burner was the necessity for fitting up an evaporator of considerable size to make up for the loss of steam which was used in the burner. The action of the flame produced by the burner was of a very satisfactory character, and boilers using it had run many thousands of miles without any mishap or difficulty of any sort or kind. In view of an attempt to obviate the necessity of evaporating plant being fitted, his firm were now experimenting with the Körting burner, Fig. 1, Plate 42, which had been used with considerable success on the "C. F. Laiesz" belonging to the Hamburg-American Co. The burner promised very well, although there was a great deal yet to be done to it.

With regard to the separation of the water, he thought he must differ from the author. It was not found in practice that the difficulty of separating water mechanically held in the oil was so great as appeared to be indicated in the Paper. A system of two settling tanks, fitted with a system of heating the oil, in one of which the oil and water could settle, had been found to work with every satisfaction, not only on Messrs. Samuel's steamers but also on the "C. F. Laiesz," which was fitted with separate tanks of that description.

The subject of the Paper was one of very great interest in the neighbourhood, even though it was a coal producing country, because a large number of steamers in the district had been fitted to burn oil, and a still larger number were now in process of construction at the various shipbuilding yards on the North East Coast, and he hoped there would be some remarks from gentlemen who had had experience, and were acquainted with the subject of liquid fuel.

Mr. Charles Hopkinson understood from the Table (page 426) that the comparison of oil with coal was from actual results, first burning coal and then burning oil. If so, he presumed the boilers were designed for the purpose of burning coal, and he should like to know whether the author had any data which would show whether some other design of boiler than that designed for burning coal was not more suitable for oil. He also wished to know whether the author had any data with regard to burning oil and coal together in steamship practice, in the same way as Mr. Holden had successfully burned them on the Great Eastern Railway. He did not quite understand what the author meant by a concentrated mixture of oil and water, as he did not know whether it was the oil which was concentrated or the water.

Mr. William Cochrane asked whether the comparison made by the author with regard to economy was simply weight of the petroleum used, because if so, it had very little effect upon the real economy, unless the price of the liquid fuel was compared with the price of coal. He hoped the author would be able to add the particulars, because although he said it was difficult to arrive at the value, yet for the general comparison it was really the chief test of the advisability of its adoption in any particular place.

Mr. J. Phillips Bedson said that, in reference to the question of comparison of costs, twenty-five years ago when creosote was exceedingly low in value—one halfpenny a gallon—it was found that creosote could be used under the boilers, burning it in a spray, and it just balanced the price of slack at 4*s.* 6*d.* a ton. A halfpenny a gallon for creosote was equal to 4*s.* 6*d.* a ton for slack.

Sir Benjamin C. Browne said the discussion had gone rather to the question of economy of oil as compared with coal, but it was desirable to know something about the relative cost of labour in the two cases, because that on a long voyage was probably more important than the actual cost of fuel.

Mr. GEORGE CAWLEY remarked that, as no speaker had so far referred to the oil-firing practice of the Great Eastern Railway, it might be timely to mention that he had been advised by the Great Eastern Railway engineers that when oil per ton was double the price of coal, the fuel cost was found about equal: that was to say, if a ton of coal cost more than half the price of a ton of oil, it was economical to use oil, and if it was the reverse, coal. He wished to know whether the author could give any similar simple relation with regard to the cost of oil-firing in steamships.

The PRESIDENT rather took it that the relative value of coal and liquid fuel on the steamship would be very different from that on the Great Eastern Railway. In the case of the steamship the fact that the liquid fuel could be stowed in such very much less space was of very considerable importance, and it would be necessary to deduct from the cost of the fuel the gain in cargo space.

Mr. ORDE said that he concurred entirely with the President's remarks, and replying to Mr. Wadia, the question of production of smoke was a most important one. It depended entirely on the combustion, and when that was complete, there should be no sign of smoke at all. As an instance, he mentioned that on a trial trip a chalked stick was inserted into the base of the funnel in the flow of the waste gases, and after ten minutes' exposure there was no trace of stain on it. With regard to the character of the coal given in the Table (page 426) as compared with oil, it was called "Good North Country quality," but as some of it was obtained in the Mediterranean and at various coaling ports on the Eastern route, he could not say anything more of its character.

He was obliged to Mr. Boyd for his remarks (page 430), and he was sure that, in offering to the Members of the Institution a practical illustration of the working of oil burners, Mr. Boyd was doing much more to explain how simple an oil-burning apparatus was than anything which he could say. The type of apparatus which Mr. Boyd would show to the Members was that employed on the "Sithonia" and the "C. F. Laiesz," so that the inspection would

be doubly interesting. He was very glad to learn that Mr. Boyd considered from his experience that the difficulty which he, the author, had foreseen in separating water from the oil was not of such great importance as he had attributed to it.

Replying to Mr. Hopkinson (page 431), the boilers in the vessels in question were designed for burning oil, so far as was compatible with good coal-burning results. The tubes were reduced in diameter and increased in length, and the depth of the combustion chamber was somewhat increased. They were, of course, a compromise, and it was no doubt possible to design a better boiler for oil fuel if it was to be used exclusively.

In reply to Mr. Cochrane (page 431), the comparison made in the Paper was based on weight alone. Prices depended on so many elements, that it was impossible in a scientific Paper to attempt to discuss it. In certain parts of the world oil could be had almost for nothing, and for vessels trading within short distances about those ports it was a great saving to burn oil, but it was impossible to lay down any general principle.

In reply to Sir Benjamin Browne (page 431), the saving of labour was a very important item. He thought he was probably within the mark in saying that an ordinary stokehold crew might be reduced by quite 50 per cent. when oil fuel was being used, and that, of course, must have a very large effect. It was interesting to hear Mr. Cawley's experience on the Great Eastern Railway (page 432). On steamers so large a ratio had not yet been obtained, and he thought it might be taken that 1 lb. of oil was equal to about $1\frac{1}{2}$ lbs. of coal of good quality.

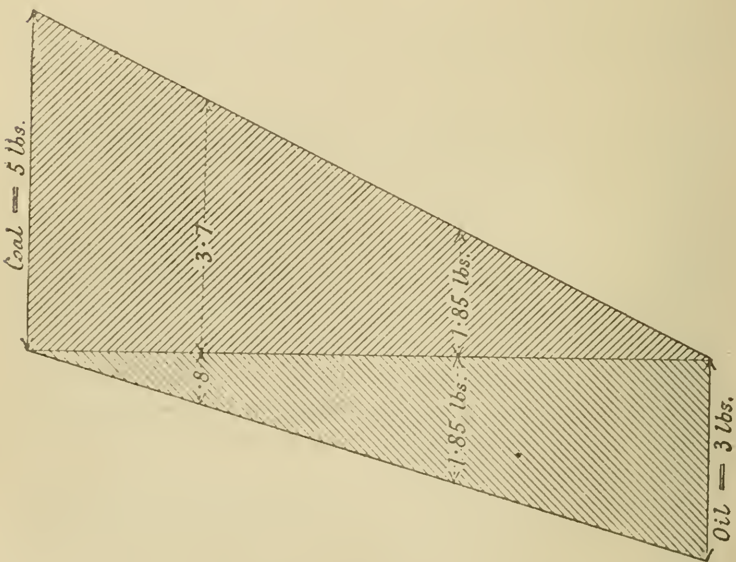
In conclusion he thanked the Members of the Institution for the very kind way in which they had received the Paper, and the interesting discussion which had been raised upon it.

Communication.

Mr. C. HUMPHREY WINGFIELD wrote that his experience was confined to experiments made with some Holden burners, Fig. 3, Plate 42, in connection with a water-tube boiler some years ago. In these experiments varying proportions of coal were burnt at the same time as the oil, and he found that the relative proportions required varied according to a straight-line law as shown in Fig. 9.

FIG. 9.

Relative weights of Coal, and Oil, required to evaporate a given weight of water from and at 212°.



Although neither fuel was tried alone, this indicated that 3 lbs. of oil would have evaporated the same weight of water (from and at 212° F.) as 5 lbs. of coal in the same boiler. The same amount would be evaporated by burning 1·85 lbs. of coal and 1·85 lbs. of oil simultaneously, as by burning 3·7 lbs. of coal and 0·8 lbs. of oil.

The question of a sufficient supply of air for combustion was an important one. In the experiments referred to, it was found advantageous to put the Holden burners near the grate so that the air passing through the latter might reach the sprayed oil after passing through a minimum thickness of the products of combustion, and so be comparatively fresh when it reached the burning oil. He did not know whether this Holden burner had since been modified, but at the time he spoke of, Mr. Holden's assistant, Mr. Bell, explained to him that the ring of jets was not, as popularly supposed, primarily intended to create a draught of induced air, but that the crossed jets acted like a screen of wires against which the oil was driven and beaten to pieces. He added that wires would answer the purpose if they did not burn away or melt. The writer believed it was important to heat the oil before it reached the end of the spraying nozzle, a point in favour of Figs. 4 and 5, Plate 43.

PUMPING PLANT FOR CONDENSING WATER.

By Mr. CHARLES HOPKINSON, *Member*, of Manchester.

The condensation of steam in the large quantities required in electric-power stations is often a difficulty in those cases where a central site is selected. Even if economy does not demand condensation, public policy does. The discharge of aqueous vapour in large quantities is intrinsically and legally a nuisance. This objection has caused trouble to users of cooling towers, and was the reason for abandoning a cooling tower scheme as part of the Newcastle tramway power plant. As an alternative it was decided to pump from the River Tyne, distant some 500 yards horizontally and 86 feet vertically from the engine-house, and to utilise the energy of the water flowing back to the river. The first idea was to use reciprocating pumps and water-pressure motors directly connected, the loss in the system being replaced by motors supplied with electric energy from the power-house. The usual course of advertisement and specification failed to elicit any suitable offer of reciprocating plant from contractors, and the centrifugal pump and turbine arrangement offered by Messrs. Mather and Platt was adopted, and the author believes that the arrangement may be found interesting in itself and possibly useful as a precedent.

The system is designed to supply at present 75,000 gallons per hour, and to be conveniently capable of expansion to supply from 150,000 to 200,000 gallons per hour, as developments may require. The general arrangements are shown on Plates 47 and 48.

The plant consists of three Mather and Platt's single-chamber high-lift centrifugal pumps; two are already installed, driven by shunt wound motors, and assisted by Gilkes' "Vortex" turbines on an extension of the pump and armature spindle. In these pumps the water enters the revolving wheel ($23\frac{5}{8}$ inches diameter) axially, symmetrically on each side of the wheel, so that axial thrust is eliminated; the water then traverses the curved internal passages between the vanes, and is discharged tangentially at the periphery, into a stationary guide ring of special construction. This ring is concentric with the revolving vanes, and conveys the water to an annular chamber in the body of the pump, where the velocity head imparted to the water by the wheel is converted into pressure head. The turbine consists of a brass wheel $13\frac{1}{2}$ inches diameter surrounded by a supply chamber, from which the water is directed on to the wheel by movable guide-vanes which regulate the flow to the wheel. After traversing the vanes of the wheel towards the axis, the water is discharged symmetrically on each side of the wheel. It will thus be seen that the construction of pump and turbine is the converse each of the other.

The pipes have been put in of sufficient size to pass the ultimate supply with a moderate loss of head. Two 15-inch suction pipes are provided, each available for the service of either of two pumps. The pumps deliver into a main 24 inches bore rising to the power-house, from which branches are taken to each surface condenser. The return water, collected in a similar main laid in the same trench, has branches to each turbine and a bye-pass direct to the tail pipe of the turbines. The levels are given in the following Table:—

Ordnance Datum	0·00
High water ordinary springs . . .	7·83
Low water ordinary springs . .	−7·17
Low water equinoctial . . .	−10·17
Pump-house floor	6·25

Centre of pump	8·22
Engine-house floor	85·9
Top of smaller condensers	85·0
Top of large condenser	97·0

The admission to the respective condensers is controlled by valves on the inlet and outlet.

It is evident that under such varying conditions of head the efficiency and duty will be somewhat variable. Tests were therefore made both with and without the auxiliary turbines at the makers' works, suction and delivery heads being obtained by throttling and the output measured over a notched weir. The following Tables and curves show the principal results:—

Fig. 3, Plate 49 .	Pump and motor only. Constant delivery: varying head and speed.
Fig. 4, Plate 49 .	Pump and motor, relation of head to delivery, speed constant.
Fig. 5, Plate 49 .	Pump, motor, and turbine. Constant delivery: varying head and speed.

A comparison of Figs. 3 and 5 shows that the addition of the turbine reduces the power required in the ratio of 108 to 62—a saving of 42·6 per cent.—about half of the saving theoretically possible with perfectly reversible mechanism. In estimating the efficiency of the whole combination, it must be remembered that the loss of head in the pipes, and valves and condensers, is constant with a given flow, and that the head so lost is not available for the restoration of power in the turbine.

The Paper is illustrated by Plates 47 to 49.

[Note.—*The discussion on this Paper was combined with that on Mr. Hunter's and Mr. Woodhouse's Papers, and commences on page* 464.]

NEWCASTLE AND DISTRICT ELECTRIC LIGHTING CO.'S POWER STATIONS.

By Mr. W. D. HUNTER, of Newcastle-upon-Tyne.

The Newcastle and District Electric Lighting Co. was formed in January 1889 for the purpose of supplying the City of Newcastle-upon-Tyne and the adjoining districts with electrical energy. The nominal capital was £50,000, and the first issue of shares was limited to £15,000. Considerable delay was experienced in obtaining the necessary powers from the Board of Trade. The interval was, however, utilized for acquiring a station, and purchasing and erecting the requisite plant and machinery. A convenient and centrally-situated station near to the River Tyne was acquired, by purchasing a portion of the Forth Banks Works belonging to Messrs. R. and W. Hawthorn Leslie and Co., which originally formed their Marine-Engine Department, previous to the establishment of the large works at St. Peters.

The station was equipped with three Lancashire boilers, 30 feet by 7 feet 6 inches, and four Parsons single-phase turbo-electric alternating generators of 75 kilowatts capacity each. The total capacity of the Forth Banks Works at present is 3,000 kilowatts. This includes two 400-kilowatt continuous-current turbo-electric generators which were erected about two years ago, to meet the

immediate demand for electrical energy for power purposes. This demand continues to grow, and in order to keep pace with it the Newcastle and District Electric Lighting Co. are now erecting at their new works in the Close two continuous-current turbo-electric generators of 1,000 kilowatts capacity each.

The Forth Banks Works are peculiarly situated on the side of a hill, the engine and boiler-rooms forming terraces one above the other. Advantage of such a site could not have been taken without great expense had it been necessary to provide substantial engine foundations, but with the Parsons turbine these can practically be dispensed with. The total area of the engine-room is only 400 square yards, and in that space, as stated above, there are fixed turbo generators representing a total capacity of 3,000 kilowatts. Water is drawn for condensers from the River Tyne. The water-pipes are laid in a brick-lined tunnel about 100 yards long, and terminate in a condenser chamber sunk to mean tide level. There are two sets of condenser plant, one for surface condensation dealing with light loads, and the other for jet condensation and capable of condensing 48,000 lbs. of steam per hour.

Plate 50 shows the engine-room, and Fig. 2, Plate 51, shows the arrangement of surface-condensing plant. The pumps are worked by an engine fitted with rocking levers and spear rods, the engine being fixed at boiler-room floor level. This plant was made by Messrs. R. and W. Hawthorn Leslie and Co., and has been at work for nine years, to the entire satisfaction of the company. Figs. 3 and 4, Plate 51, show the arrangement of jet-condensing plant, which was specially designed to take advantage of the position in relation to the River Tyne. The water-pumps are situated at mean tide level, the air-pumps only deal with air and vapour, and the jet water rises to a considerable height in consequence of the vacuum formed; the "head" against the pumps at the bottom of the well is therefore comparatively small; the vacuum obtained is generally within an inch of the indications of a standard barometer. The contract was carried out by Messrs. John Abbot and Co., of Gateshead, the pumps being supplied by the Worthington Pumping Engine Co., and air-pump engines by Messrs. Carrick and Wardale,

of Gateshead. The cost of repairs and renewals for this plant during the six years it has been in operation, is practically represented by the cost of inspection.

Close Works.

The site of the new works, at present being constructed and equipped, is immediately on the side of the River Tyne, situated about midway between the High Level and Redheugh Bridges. The works when completed will have a capacity of 12,000 kilowatts, or about 20,000 indicated horse-power.

The engine and boiler-rooms, with coal-store overhead, run parallel with the river from which the circulating water for condensers will be drawn. Coal will be brought to the works in barges and conveyed to the coal-bunkers and furnaces by special plant. The workshops, stores, &c., will be situated at the east end of engine-room, where provision is left for building these on. The cross section, Plate 52, shows clearly the relative positions of the various parts of the machinery, and the photograph, Fig. 7, Plate 53, gives a back view of the boilers. The following is a brief description of the more important parts of the plant.

Turbo-Electric Generators.—The two generators are each of 1,000 kilo-watts capacity, the electromotive force being 500 volts and the speed about 1,800 revolutions per minute. By adopting this size of generator, excellent results in regard to economy of steam are obtained, as will be seen from the following Table (page 444), giving particulars of a test made at Heaton Works on one of the generators for the Newcastle and District Electric Lighting Co.'s Close Works.

Plate 54 is a photograph of the generator tested as above. It will be observed that the machine is of the tandem form, and had really two dynamos, each of 500 kilowatts capacity. The armatures are interchangeable, and if necessary one dynamo may be run independently of the other. The steam-turbine portion of the generator is of the makers' latest improved construction, and is arranged for the full expansion of steam from the boiler pressure to

Speed.	S. V. P.	Cyl. Vac. 30″ Bar.	Superheat. F°.	Volts.	Average Kw.	Water.	
						Lbs. per hour.	Lbs. per Kw.-hour.
1690	138	26	71	500	1011·6	21734	21·48
1680	140	26	86	500	909·0	18610	20·47
1700	142	26·2	128	500	894·6	17760	19·85
1660	144	26·3	132	500	890·7	17020	19·1
—	144	26·3	135	500	882·9	17171	19·43
1700	145	26·3	137	500	874·04	16983	19·43
—	145	26·3	137	500	901·06	17500	19·42
1680	146	26·3	136	500	896·7	17302	19·29
1640	142	26·4	136	500	862·2	16479	19·11
—	142	26·6	133	500	877·2	16800	19·15
1640	146	26·3	131	500	944·17	17903	18·96
1660	140	26·3	142	500	986·6	18434	18·78
1710	135	26·3	146	500	942·5	17559	18·52
1710	135	26·4	182	500	942·6	17460	18·52
—	140	26·5	195	500	878·06	15857	18·06
1710	146	26·6	221	500	863·28	15493	17·94
—	145	26·5	237	500	897·84	15922	17·73

It should be noted that these results were obtained when the machine was running some 10 per cent. under full load. At full load, with a 27-inch vacuum and 240° F. superheat, the consumption would fall to about 17·0 lbs. per kilowatt-hour.

that corresponding to within one inch of the barometer. The expansion is carried out in three barrels or cylinders of definite length and diameter to suit. The revolving portion is carried on large journals, and transmits the power to the armatures through a special claw coupling arranged at one end. At the opposite end a worm and thrust collars are fitted, the former being geared to a wheel which works the oil-pump for automatic lubrication by means of a crank-disc shaft. The fixed portion of the cylinder is designed to rest upon the supports provided at each end and at the exhaust, the foot is rigidly bolted to the bedplates, while at the

steam end provision is made for the foot to slide on the pedestal without altering the alignment; provision is thereby made for any alteration due to expansion.

It will be observed that steam is brought right on to the cylinder top, and is controlled by suitable valve gear as near to the working shaft as possible, so that all losses are minimised. The steam enters the first chamber and passes the "runaway" valve, which under ordinary working conditions is open; the steam is then in contact with the working valve, and the quantity passing is controlled by means of the steam relay gear fixed directly above. This gear is automatic in its action, and works in conjunction with an electrical solenoid. In addition, there is provided a pulsating motion to keep all parts of the lever and valve gear in movement, and to ensure prompt action on any change of load being made. The electric solenoid is energised by the main circuit, and maintains automatically constant voltage at all loads. The action is as follows: Should the voltage rise above the normal on change of load the solenoid core is lowered, and a small balancer piston hung at the opposite end of the lever is raised a proportionate amount; this allows the steam which keeps the regulating valve in action to escape more quickly, and the valve closes a little. If the voltage falls, the opposite effect is produced, and so quick is the response to any change of load that it is easy to maintain the pressure within 2 per cent. of the normal.

The dynamos are of the latest type, and embody all the improvements which experience alone can show to be desirable. Great care is taken to ventilate the armature thoroughly, and as much skill is required to effect a balance, extra attention is given to the various parts both before and after they are assembled on the shaft. The brush rocking-gear is very interesting; it is automatic in its action, and is controlled directly from the steam cylinder. The effect is to place the brushes instantly on the best working position of the commutator, no matter what the change of load may be. The floor space occupied by each machine is 38 feet 6 inches by 6 feet, or only 231 square feet area.

The heaviest parts do not exceed:—

Cylinder Bottom	. . . . . .	$5\frac{1}{4}$ tons.
„ Cover	. . . . . .	$3\frac{1}{2}$ „
„ Shaft	. . . . . .	$2\frac{1}{2}$ „
Armature	. . . .	3 „

Mr. Parsons kindly lent the author a model, which was exhibited, of a 4,000 kilowatt generator, which gave an excellent idea of the proportions of this large machine.

Boilers.—The five boilers at present erected were made by the Stirling Boiler Co.; they are illustrated in Fig. 7, Plate 53, and Plate 55. Each of these boilers is capable of evaporating 18,000 lbs. of water per hour at 250 lbs. pressure per square inch. The boilers are fired with chain grate stokers, which work with absolute smokelessness in this type of boiler. Each boiler consists of three top drums and two lower water drums connected by banks of tubes. The feed is admitted to the back top drum, passes down the last bank of tubes, and thereby comes in contact with the hot gases before they leave the boiler, thus reducing the chimney temperature to a minimum. The feed-water being heated in its passage down the back bank of tubes deposits mud and sediment in the bottom drum, whence it can be readily blown off, and as this drum is far removed from the fire no injury will result from a considerable accumulation of solid matter in same. This arrangement of the boiler thus has an economiser and purifier action, so that if there is any deposit, it takes place in the rear position and the water is purified before reaching the tubes over the fire. With the special design of combustion chamber, shown surrounded on three sides with fire brick, a high initial temperature is obtained, thus ensuring perfect combustion and an absence of smoke; it also admits of an inferior quality of coal being burned with high efficiency. The design of the boiler is simple, as the tubes are expanded direct into the drums, and access to the interior is obtained by opening five manhole doors. The makers supply a simple arrangement for cleaning the interior of the tubes, and provision is made for a steam-jet to blow soot off the outside surfaces. The author obtained from the Stirling Boiler Co. a working model of one of their boilers, which was put in

operation at the meeting to show the manner in which the water circulated.

Boiler Feed Pumps.—The Boiler Feed Pumps, Fig. 6, Plate 53, are supplied by Messrs. G. and J. Weir, Cathcart, and consist of two of this firm's well-known standard single direct-acting pumps, each $9\frac{1}{2}$ inches diameter water cylinder by $12\frac{1}{2}$ inches steam cylinder and 24 inches stroke. These pumps are single cylinder double-acting and vertical. The pump ends are of cast-iron fitted with gun-metal liners, and the pump rods are of cold rolled manganese bronze. The valve gear is positive, that is, the steam valve can never be in such a position that the pump will not start immediately steam is turned on. In these pumps the steam is used expansively, and the cut-off can be regulated from the outside, while the pumps are working, thus making them extremely economical as regards steam consumption. The pumps are very simple, and all the parts are readily accessible.

Coal Conveying Plant.—The type of coal conveying plant has not been definitely fixed upon; four alternative designs are illustrated in Plate 56. In each case the plant is designed to discharge the coal from barges as they come alongside the jetty or quay wall, afterwards distributing it along the coal bunkers in front of the boiler-house, whence it is fed into the hoppers of mechanical stokers.

Fig. 10 (Scheme *A*) is a design by Messrs. Barry Henry and Co., of Aberdeen. The electric cranes are fitted with Hone's grabs, capable of holding one ton of coal. These deliver into Ingrey's registering weighing machines, from which the coal is taken to the bunkers by means of elevators, and distributed by means of a push plate conveyor. A weighing and recording machine is provided for each boiler, so that by comparing the total weight of coal received and the weight of coal burned, the stock can be correctly ascertained.

Fig. 11 (Scheme *B*) illustrates the design submitted by Messrs. Babcock and Wilcox. The conveyor consists of a double-link chain carrying a series of pivoted buckets suspended in such a

manner that they maintain their vertical positions, and are free to revolve on their axles at all points of their path, excepting those points at which it is necessary to dump or empty them, and this dumping is automatically performed in a very simple and efficient manner, by means of a cam action, whilst the buckets on being released from the dumpers right themselves and are ready to be refilled. The system of buckets passes through the cycle of its action, continuously filling and emptying, or "dumping," at any position arranged for them, this being performed by merely moving a small lever. Ashes can be dealt with independently or simultaneously with coal in this type of conveyor, and by means of an ash hopper situated under some part of the conveyor run, ashes can be stored until a convenient time for their removal, when they can be discharged by means of a special controlling valve into any conveyance that may be used.

The design submitted by Messrs. E. Bennis and Co., of Bolton, is illustrated in Fig. 12 (Scheme *C*), and shows that the whole apparatus is contained in a small space and that the arrangements made for actuating the grab and distributing the coal are very complete.

The proposal submitted by Messrs. Graham Morton and Co., Leeds, is shown by Fig. 13 (Scheme *D*), and provides for taking the coal from barges by means of two grabs worked by electric cranes. It is then passed through a weighing machine and elevated to the bunkers, over which it is distributed by means of a push plate conveyor. The coal to each boiler is measured by means of a special machine which registers the amount contained in a revolving apparatus.

All the above designs embody many interesting points which cannot be touched upon in a Paper of this description.

A 15-ton overhead traveller, supplied by Messrs. Vaughan and Son, Manchester, spans the Close Works engine-house. The girders and end carriages are of the box riveted type, the latter being each fitted with two steel-tyred travelling wheels. The crab is carried on four steel runners, keyed on steel axles revolving in gun-metal bearings; spur gearing is used throughout, the whole being

machine-cut with the exception of the barrel wheel and pinion. In conjunction therewith a magnetic brake is provided to sustain the load. When current is switched on to the hoisting motor, it puts into circuit an electro-magnet possessing sufficient power to raise the brake lever, and render the brake inoperative at the moment that hoisting or lowering commences, and also during their continuance. Directly current is switched off the motor, the brake applies itself automatically and without any attention whatever on the part of the operator. The advantage of this is obvious, as if from any cause during working operations the current should fall, the brake magnet would instantly release the brake and allow it to take charge of and sustain the load. There are two barrels, each machine-grooved and fitted with wire rope; the large barrel has right and left-hand grooves to secure vertical lifting and equal distribution of load on both girders. Both barrel hooks revolve on hardened cast-steel balls and plates.

The speeds of the crane are as follows :—

Hoisting,	15 tons at	4	feet	per	minute.		
,,	7½ ,, ,,	8	,,	,,	,,		
,,	2 ,, ,,	30	,,	,,	,,	small barrel.	
Longitudinal traverse,		200	feet	per	minute		light.
Cross	,,	100	,,	,,	,,		light.

By regulation of the controllers the above speeds can be varied instantly from maximum to zero. The three movements of the crane are effected by three series-wound motors, each having its own controller, the latter being carried on the crab and operated by cords from the ground floor. The powers of the motors are :—

Hoisting,	6 H.P. at 300	revolutions	per minute.
Longitudinal traverse,	6 H.P. at 600	,,	,,
Cross ,,	3 H.P. at 300	,,	,,

For short periods these are capable of developing double their rated powers. In connection with the hoisting gear, a stop motion is provided for the purpose of automatically breaking the circuit and preventing overwinding. The efficiency is about 50 per cent., the loss including all the mechanical friction of the gear as well as that of the motor.

Condensing Plant.—The condensers and pumps, which are shown in the cross section of the buildings, Plate 52, were made by Messrs. John Abbot and Co., of Gateshead. The condensers have each a cooling surface of 3,000 square feet; ample provision is made for examination by means of large doors, and the internal arrangements are all in accordance with the latest Admiralty practice. The pump cylinders are fitted with liners, and have rods of Delta metal. Ample passage ways are provided in the circulating pump so that the velocity of water never exceeds 4 feet per second at any part. The engines for driving these are of the vertical compound type, with provision for admitting high-pressure steam to low-pressure cylinder for starting. The bedplate is bolted to fixed girders above the pumps, and two heavy balanced fly-wheels are provided. The pump-rods are balanced by means of rocking levers and weights worked off the cross-heads. The engines were made by Messrs. Carrick and Wardale, of Gateshead.

Switch-board.—The switch gear is of the cellular type, constructed by Messrs. Ferranti, and consists of heavy black enamelled slates grouted into the station wall, and divided off into a number of pigeon-hole recesses by vertical division slates, the principle being to have a complete compartment for each apparatus used on the gear. The switchboard comprises six dynamo panels. Plate 57 represents a general arrangement view of the entire switchboard, from which it will be seen that each of the six dynamo panels on the right include the following:—voltmeter; ammeter; two single-pole switches with reverse current automatic devices; and section of regulating table on which the open type regulating resistances are controlled by means of a hand-wheel. In the centre of the board will be seen a large 6,000 ampère watt-meter placed between the bus-bars to register the total watts generated by the machines. An earth recording ammeter with cut-outs and one mid-wire ammeter are placed under the watt-meter panel in the regulating table. Continuing to the left will be seen provision for two balancers complete with main switches, ammeters, and starting resistances. The three-wire feeder panels are arranged to the left of the board,

and each panel comprises 2 voltmeters, 2 ammeters, 2 switches, and maximum current automatic devices provided with time limit relay. Each generator and feeder panel is designed to carry 1,000 ampères, and to break under the severer conditions likely to be existent under emergencies. In designing this gear it has been the aim to simplify the connections to a minimum degree consistent with the efficiency and convenience of working. As a result the entire arrangement is simple and easy for the operator to understand, and having all connections clearly visible before him there is very little opportunity for errors to be made, which otherwise might lead to disastrous results. It is impossible to place too great stress upon the necessity of rendering the switchboard free from fire risks. The theory of splitting up the whole into small compartments has been carefully considered with this in view. Moreover, there is an absence of inflammable material, and when compared with the old flat board type of switch-gear, it is not only interesting but eminently satisfactory to see the way in which strip cable connections are avoided. The cellular type of switch-gear as constructed by the Ferranti Co. has been very widely supplied to high-tension alternating current systems. The advantages thereby derived are so obvious that although the continuous-current board is only of recent introduction, yet it is already becoming a standard type for continuous current purposes.

The Paper is illustrated by Plates 50 to 57.

[NOTE.—*The Discussion on this Paper was combined with that on Mr. Hopkinson's and Mr. Woodhouse's Papers, and commences on page* 464.]

ELECTRIC-SUPPLY POWER-STATION AT NEPTUNE BANK, NEWCASTLE-UPON-TYNE.

By Mr. W. B. WOODHOUSE, *Associate Member*, of Wallsend-on-Tyne.

The Newcastle-upon-Tyne Electric Supply Co. has the distinction of being the first to supply electric power in bulk in this country. The Walker and Wallsend Union Gas Co. obtained an Act of Parliament in 1899, authorizing supply in Wallsend and Willington, a district of great manufacturing importance, extending along the riverside. The Supply Co. having in view the construction of a new power-station entered into an agreement with the Gas Co., whereby the latter took power in bulk from the Supply Co., and distributed to its own customers, Fig. 6, Plate 58. That portion of Newcastle originally supplied from the Pandon Dene Station, the Walker Urban District and Gosforth, are included in the area in which the Supply Co. is authorized to distribute power. The whole scheme has been developed and carried out by Mr. Charles H. Merz, consulting engineer to both companies.

The station started to supply power to local works in November, 1900. Three-phase currents, at a pressure of 5,500 volts and a frequency of 40 cycles per second, are transmitted to the various sub-stations, in which, by means of synchronous motor generators and stationary transformers, conversion is made to 480 volts direct

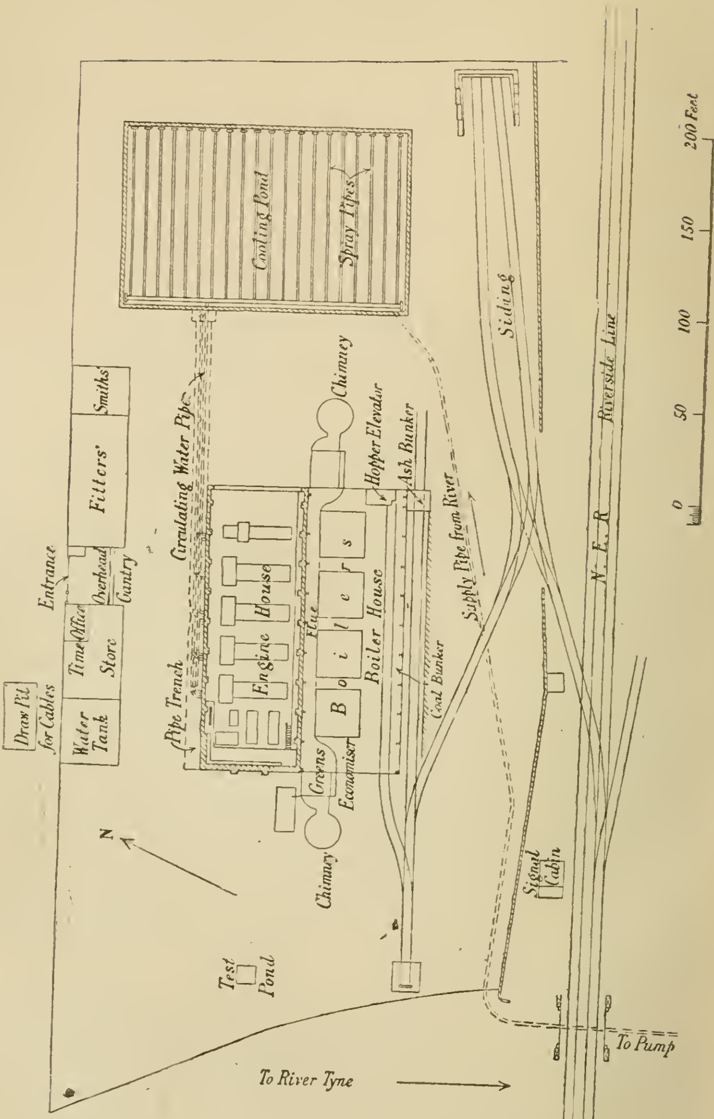
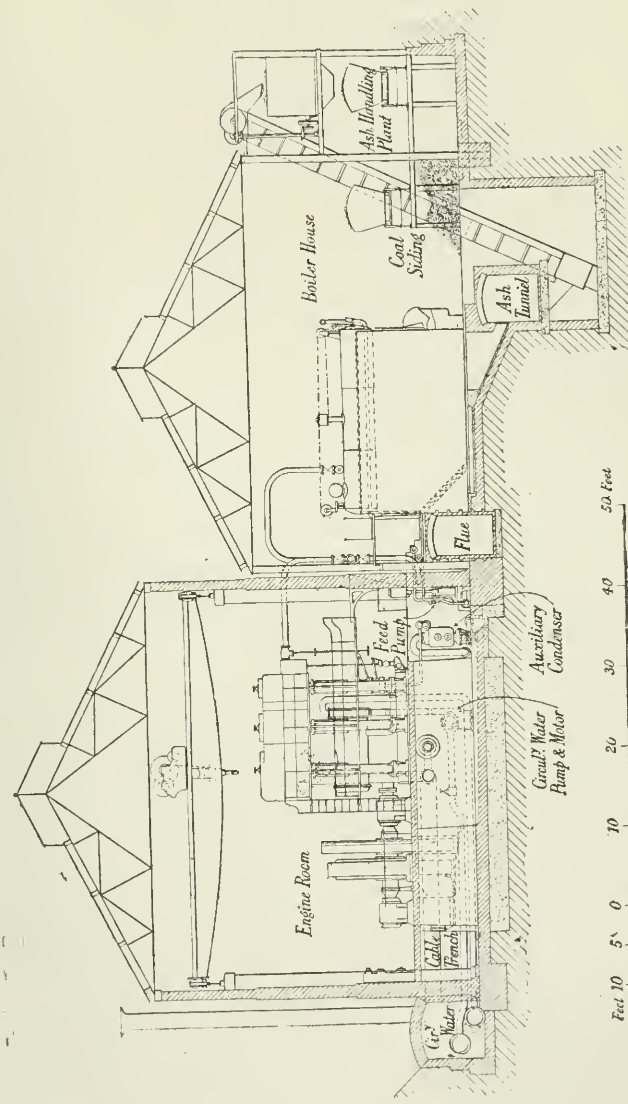


Fig. 1.—General Plan.

Fig. 2.—Transverse Section.



current for power and lighting on the three-wire system, and to 440 volts alternating three-phase currents for power alone. The station, Fig. 1 (page 454), is some 350 yards from the river, and stands next to the Riverside Line of the North Eastern Railway, from which there is a siding. Coal is delivered to this siding and the trucks are handled by a small electric locomotive, running on an elevated track to the boiler-house, on the floor of which the coal is deposited.

Boiler-House.—This is a steel and corrugated iron building, 160 feet long and 52 feet wide; its floor is on the same level as the engine-room basement, Fig. 2 (page 455). It contains eight Babcock and Wilcox boilers, supplying steam at 200 lbs. per square inch pressure, with a superheat of 120° F. The superheaters are situated between the drums and the main tubes, and the degree of superheat of the steam delivered is adjusted by diluting it with saturated steam. Each boiler has a heating surface of 4,020 square feet and a grate area of 74 square feet, and is capable of evaporating 14,000 lbs. of water per hour from and at 212° F. Two of these boilers are fitted with Vicars' stokers and four with the Babcock and Wilcox chain grate; the stoker gear is electrically driven and takes a maximum of 5 H.P.

Fuel.—The Fuel burnt is Northumberland small coal having a calorific value of about 11,000 B.T.U. per pound; and with natural draught about 23 pounds per square foot of grate area is burned per hour. The ashes are discharged into trucks in the ash tunnel below the boiler-house floor, and are lifted from a hopper, at the end of the tunnel, by a bucket elevator to a large hopper outside the boiler-house; from this hopper the ashes are discharged into railway trucks. The main flue, which is of brickwork, runs the whole length of the boiler-house; at the west end is a Green's Economiser of 280 tubes and a steel chimney lined with firebrick, 130 feet high and 6 feet 9 inches diameter at the top; at the east end a similar economiser and chimney are in course of erection; at this end is an induced draught fan direct coupled to a three-phase motor.

As the cost of coal is the most important item in the production of electrical energy, complete combustion is of primary importance, but it is also of importance to obtain the maximum evaporation from the boilers installed. Where no economiser is used and the flue gases at the base of the chimney have a temperature of 500 to 550° F. a good draught can be usually depended on, but where, due to an economiser, this temperature is, say 250°, then one is at the mercy of climatic conditions, the boilers cannot be worked to their full capacity, and up goes the cost per unit. If the capital charges per unit are to be kept low, induced draught becomes a necessity.

The steam-pipes are of solid drawn steel tube, the main header extending the whole length of the boiler-house; the valves are so arranged that any boiler and the engine behind it may be isolated from the rest of the steam plant. The Belliss engines and the feed pumps are not supplied direct from the main header but from a smaller pipe, running along the boiler-house below the level of the engine-room floor.

The efficiency of a power-station can only be maintained by systematic and regular tests of all the plant in the station; the boiler-house economy is of first importance. In addition to making periodic tests on the evaporative power of the fuel employed, two instruments are in use that deserve mention. The first, known as Arndt's Econometer, indicates continuously the percentage of carbon dioxide in the flue gases; it is essentially a delicate balance, one scale-pan being replaced by an inverted glass jar. A sample of the flue gases is drawn through this, and a variation of density causes the pointer of the balance to deflect; as carbon dioxide differs largely in density from the other flue gases, a scale beneath the pointer is graduated to read the percentage of carbon dioxide present. The fact that one can see at a glance the effect of any change in the firing of the boilers is of great value. Leaky flues may be detected by means of an Orsat apparatus, by which a volumetric analysis of the flue gases is readily made; the percentage of free oxygen is estimated at various points in the flue, an increase showing a leakage of air. Pockets for thermometers are provided in the various steam and water pipes, and the boiler feed is measured by a Kennedy water meter.

Engine Room.—This room is 160 feet by 52 feet and the general arrangement is shown in Fig. 1 (page 454). The Weir feed pumps and the motor driven centrifugal circulating pumps are in the basement, the boiler feed can be drawn from either of two hot-wells situated at the ends of the building or direct from the water service main. Direct current is generated for station power and exciting, and for the Wallsend network; the dynamos for these purposes are of British Thomson-Houston Co.'s manufacture, and are direct coupled to Belliss and Morcom engines; two of 300-B.H.P. running at 380 revolutions per minute, and one of 75 B.H.P. running at 500 revolutions per minute.

The engines for the three-phase generators are all of local make. A brief description follows:—One 1,400-I.H.P. engine by Messrs. The Wallsend Slipway and Engineering Co. This is a three-crank triple-expansion engine with cylinders whose diameters are 17·5 inches, 28·5 inches, and 48 inches, the stroke of each being 36 inches, running at 100 revolutions per minute, Fig. 4, Plate 58. The cylinders are jacketed, with reducing valves at the M.P. and L.P. jackets; when running at three-quarter load with superheated steam, the efficiency is much the same with jacketed and unjacketed cylinders; at light loads the jacketing is advantageous. The Corliss valves are worked by rocking levers from the crank-shaft eccentrics; governing takes place on the H.P. cut off only, by means of a Whitehead spring governor and trip gear. The condenser and air pump are mounted on the back frame of the engine with the circulating pump in the basement beneath it. The magnet wheel and fly-wheel are mounted on one shaft carried by spherical seated bearings with continuous oil lubrication; the extreme diameter of the wheel is 17 feet, and it weighs about 43 tons. Of exceptional interest are the figures of the steam consumption of this engine given in Table 1 (page 463). Through the courtesy of Mr. Andrew Laing, the author is able to give the combined cards at full load and three-quarter load, Fig. 3 (page 459).

There are three 1,400-I.H.P. triple-expansion four-crank engines, made by Messrs. Wigham Richardson and Co.; these engines are fitted with crank-shaft governors with shifting eccentrics, and govern

on the H.P. and M.P. cylinders. The H.P. and M.P. cylinders have double-beat valves and the trip gear is very compact. The engines are balanced for primary forces and couples, so that the cranks are necessarily not at right angles; due however to the four cranks, the variation of crank effort is small. The situation of the air pump, condenser, etc., is as in the Slipway engine.

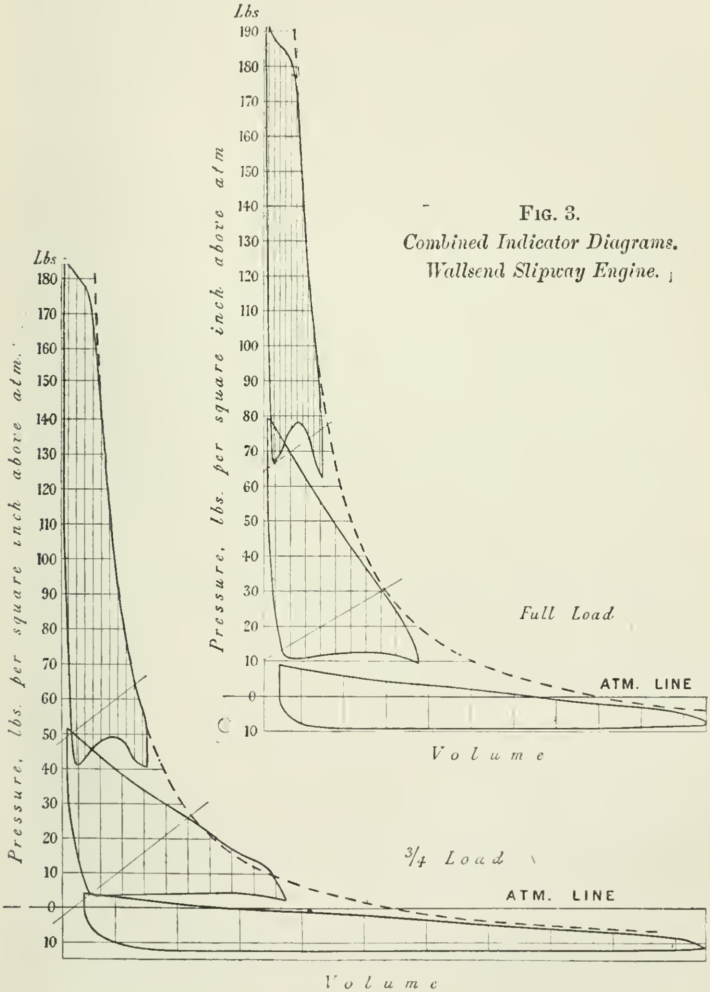


FIG. 3.
Combined Indicator Diagrams.
Wallsend Slipway Engine.

All these engines are direct coupled to three-phase generators with stationary armatures and rotating magnets, made by The British Thomson-Houston Co.

One 1,500-kilowatt turbo alternator by Messrs. C. A. Parsons and Co., running at 1,200 revolutions per minute. The alternator is direct coupled to the turbine and is mounted on its own bearings; a forced circulation of oil and cooling water passes round each bearing.

The air pump and condenser are situated beneath the turbine, the three-throw air-pump being direct coupled to a slow speed motor running at 100 revolutions per minute. The circulating pump is direct coupled to a 45-H.P. motor.

As a prime mover of electrical machinery the steam turbine approaches the ideal; it runs steadily, is free from vibration, and needs little attention; the question of steam consumption has been the difficulty.

In a communication made to this Institution last year,* the steam consumption per kilowatt-hour was given for a number of turbines; the figure steadily improved with the size of the machine. The Neptune Bank Turbine bears comparison best with that supplied by Messrs. Parsons to Elberfeld, a machine of 1,000 kilowatts output. The figures of a test made at Neptune Bank are given in Table 2 (page 463), from which it will be seen that the Elberfeld results are beaten.

With units of 3,000 to 6,000 kilowatts output, such as will be demanded in the near future, the turbine promises to outstrip all competitors.

The author is indebted to the Hon. C. A. Parsons for Fig. 5, Plate 58, showing the machine.

Parallel Running.—The following are the considerations governing the design of engines driving alternators in parallel. All these engines are direct coupled to alternators which have to be run in parallel, and a large portion of whose load consists of synchronous machinery. If at any instant there be a phase difference between

* Proceedings, 1901, page 808.

two alternators in parallel, that is, one alternator ahead of the other in phase, there will be a cross current flowing between them, the synchronising current tending to draw them together into phase. An irregularity of torque, such as that due to uneven crank effort, will cause an alternator to swing ahead of the co-phasal position and return to an out-of-phase position in the opposite direction, the synchronising current exerting a controlling force proportional to the phase displacement. A continuation of the swinging may be aggravated by external circumstances, such as a periodic variation of the load due to the inertia of synchronous motors on the system; and although a heavy flywheel on the engine smoothes out the irregularities of torque, yet once the "hunting" has started, the flywheel tends to keep up the hunting.

Again, as the engines are required to take their share of all loads, it is important that the drop in speed from no load to full load shall be the same in each engine.

As a variation of velocity occurs twice in a revolution with a single-crank engine and eight times in a revolution with a four-crank engine, it is obvious that, for the same percentage variation of angular velocity, the phase displacement will be four times as great with the single-crank engine. The engine specification should therefore refer to phase displacement and not to variation of angular velocity. With modern alternators the maximum phase displacement should not exceed 6 degrees, equivalent to a synchronising current about 10 per cent. of short circuit current; degrees of phase displacement being degrees of angular displacement multiplied by the number of pairs of poles in the magnet wheel. With a high-speed engine the allowable angular displacement becomes greater, for with the same frequency of alternation the number of poles is less.

There are several methods of measuring a variation of angular velocity, the best known being the use of a tuning fork to trace its vibrations on a paper cylinder driven by the engine; electrical methods, such as driving a small direct current dynamo from the flywheel; the most sensitive is the stroboscopic method used in conjunction with photography.

As a means of observing extreme cyclic irregularity and hunting, the Horn Tachograph is to be commended; it records the variation of

speed on a moving paper, and greatly facilitates the setting of the engine governors to give the same percentage drop of speed on load.

Once hunting is started, by whatever cause, the sensitiveness of the governor becomes of importance; in this connection it may be mentioned that a dash-pot designed with a large and a small by-pass has been found successful in many cases. The main by-pass is normally closed by spring valves, thus reducing the sensitiveness of the governor; but on a change of load the pressure of the plunger continues long enough to open these valves until equilibrium is restored.

Cooling Pond.—The circulating water for the condensers is cooled in a Körting cooling pond, Fig. 1 (page 454), the water being sprayed through nozzles into the air. Over a portion of this pond stand the car-sheds of the Tyneside Tramways Co.; the pipes carrying the spraying nozzles are led in flues, through which a rapid circulation of air is caused by means of an exhausting fan.

The make-up water is pumped from the river Tyne by a three-throw Pearn pump situated close to the river; this pump is electrically driven, and is started and stopped from the power-house.

Switchboards.—The high tension switchboard was made by Messrs. Ferranti, and is divided into panels for the various machines and feeder cables. The machine switches and all fuses break circuit through oil. Two sets of watt-meters are fitted for metering the power supplied to the Gas Co. and the Supply Co. respectively. The direct current switchboard, made by Messrs. Reyrolle, is in three sections. The panels carrying the field and compounding switches are beneath the gallery; the panels on the gallery carry the machine switches, ammeters and voltmeters, and the feeder panels beneath are fitted with circuit breakers and watt-meters. The cables and instruments used in connection with a water-testing pond for artificially loading any machine in the station, are a permanent arrangement; as above mentioned systematic tests are part of the station routine.

The resident engineer during the construction of the station has been Mr. H. L. Riseley.

TABLE 1.

Steam Consumption of Slipway Engine at various loads.

Pounds of water per hour.		Mean total.	
per I.H.P.	per kw.	I.H.P.	kw.
10	21·8	364	163
10·03	18	594	331
9·94	16·89	850	503
10·42	17·09	1177	719

TABLE 2.

Steam Consumption Tests of Slipway Engine and Parsons' Turbine.

		Slipway Engine.	Parsons' Turbine.
Mean revolutions per minute		101·2	1200
Mean total	I.H.P.	1030	—
Mean total	kilowatts load	625	1442
Pressure of steam at engine stop valve	lbs. per sq. in.	193	196
Superheat	°F.	90·5	76
Vacuum in condenser	ins.	26	27
Pounds of steam	per I.H.P. hour	10·35	—
Pounds of steam . . .	per kilowatt hour	17·1	18

The Paper is illustrated by Plate 58 and 3 Figs. in the letterpress.

Discussion on the foregoing three Papers.

Mr. CHARLES HOPKINSON said he had written his Paper simply as a description of what he hoped some of the members would see. They would notice the excessively thick walls in the pump-houses, and the meaning of such walls was that it was possible at some future date a warehouse might cover up the pump-house. Enormously heavy beams carried the concrete roof, and that was also because the floor might be heavily loaded above. It was not extravagance, but precaution for the future. Another point of interest was that the quay wall had to be cut through, and the engineer would not allow him to go through the wall, except at the joints of the monolithic blocks of which the wall was built, and consequently he had to go through in three places, with the consequent cost of over £1,000, to get his pipes into the water. He had not put anything relating to cost into the Paper, because the cost questions were altogether a matter of a particular place and particular circumstances. In his own case with a tramway station with a splendid power factor—running something like twenty hours a day—where the water supply, if water was not pumped from the Tyne, would have to be obtained from the company's supply at a considerable cost per annum, some compensation was afforded for the disadvantage of having to convey the pipes through the streets where the way was obstructed by sewers, gas-pipes, water-pipes, and tramway lines. The total cost, therefore, for the delivery of the amount of water had been somewhat excessive, and he estimated it at something like £10,000. But although that was a large amount, it had a very profitable return. The running cost was much less than if a non-condensing plant had been run. In case there might be some cooling-tower advocates present, it might be advisable for him to point out that he could not use a cooling tower, because of the nuisance to the neighbours, and he was obliged to work condensing in any case. He was bound to go to the river, and had to go in the best way possible.

Mr. Mark Robinson, Member of Council, thought both Mr. Hunter and Mr. Woodhouse would add to the value of their interesting Papers, if in the statement of the steam consumption of the respective engines they would give the heat-units contained in the water used; for both the value and the cost of a pound of steam varied with the extra heat-units, if any, which were put into it by superheating. So long as the water or steam, and the heat contained in it, bore an invariable relation to each other, as was the case when an engine used saturated steam, it was perhaps not seriously misleading to attempt to express the expenditure of heat in terms of weight of steam used. But such a method became altogether misleading the moment the old invariable relation between pressure and temperature was destroyed by superheating, and therefore in engines using superheated steam it was important not only to know the amount of superheat, but to have the consumption worked out in heat-units per I.H.P., or per kilowatt, as the case might be.

Professor W. J. Lineham said all the members were interested in comparing steam turbines with reciprocating engines, and he had one or two remarks to make upon that subject. In Mr. Hunter's Paper there was rather an astounding statement that the steam turbine portion of the generator was arranged for the full expansion of steam from the boiler pressure to that corresponding to within one inch of the barometer. Was it to be understood from that, that it was within half lb. of vacuum? It did not appear to agree with the Table (page 444), where there was a cylinder vacuum of from 26 inches up to 27 inches. In Mr. Woodhouse's Paper was given a Table of results of the Slipway engine at various loads, and in Table 2 (page 463) a comparison was made between the Slipway engine and the Parsons turbine, but there was not given for the turbine a series of results with varying load. He considered the paragraph in Mr. Woodhouse's Paper (page 461) to be highly interesting to a mechanical engineer who had to make engines to turn dynamos. It really appeared to him that the triple-throw engine ought to give a more steady condition of running than the

(Professor W. J. Lineham.)

4-crank engine, and he should like to see some comparison made between the two sets of engines, the triple-throw engine of the Slipway Co. and the 4-crank engine of Messrs. Wigham Richardson and Co.

Mr. Daniel Adamson said Mr. Woodhouse had given comparisons between the steam consumption of the 3-crank engine and the steam turbine, but there were no figures given as to the results of the 4-crank engines. He thought it would be interesting to the Institution to see the result of any trials with the 4-crank engines to compare with the other trials mentioned in the Paper.

With regard to Mr. Hopkinson's Paper, he desired to know what result was expected with the water lifting and returning arrangement, when all the three plants were used? Would not the greater loss in the return pipe under those conditions affect the saving—not the percentage of saving possible—but the actual saving realised, for the reason that owing to the increased loss in the return pipe, due to the much larger volume of water passing, there would be a smaller proportion of energy available at the turbines on the return journey?

Mr. Henry Lea, Member of Council, referred to Mr. Woodhouse's remark (page 460) with regard to the Parsons' turbo-generator, "As a prime mover of electrical machinery the steam turbine approaches the ideal; it runs steadily, is free from vibration, and needs little attention; the question of steam consumption has been the difficulty." The speaker had had some turbo-generators in use for six or seven years of about 160 I.H.P. each, and they had given no trouble in the running. The steam consumption had been a difficulty, but steam consumption alone had not to be considered. At the time when the turbos were purchased, six or seven years ago, they were able to be bought at about half the price of a reciprocating engine of the same power, consequently there was a saving in interest on the amount of capital by buying the cheaper engine, and when the account came to be balanced it was found that although the turbines were certainly comparatively wasting steam, being non-condensing,

yet the account was squared by the saving in interest on the smaller capital. The other turbines he had used had been condensing, and he had nothing but praise for them; the economy was great, the consumption of steam was less per kilowatt than Messrs. Parsons guaranteed it to be, and the machines ran year after year with very little attention, and absolutely no repairs up to the present.

Mr. Woodhouse had also referred to the measurement of angular velocity by the use of the tuning fork. He, Mr. Lea, did not know whether many members of the Institution had had the pleasure of seeing Duddell's oscillograph, a little machine which actually drew a picture of the electromotive curve of an alternating current, and presented it on a piece of glass over which a tracing paper might be placed, and the shape of the alternating curve drawn. In the case of two alternators not quite in phase, if one of the two reflecting galvanometers of the instrument were connected to the terminals of one of two alternators and the other to the other, the synchronous motor of the instrument being driven from one alternator only, then the curves shown simultaneously by the instrument would be those of the two alternators, and from the lineal displacement of the curves, the angular displacement of the revolving parts of the two alternators could readily be ascertained. If the asynchronism of the alternators varied, so would the curve displacement vary in the picture. If and when the two machines fell into step the curves would coincide, unless they differed in shape, when such difference would be plainly seen, incidentally a very important advantage. He did not think he had experienced much greater pleasure in looking at instruments than he derived in looking at that oscillograph, which was kindly shown to him in Cambridge a few weeks ago. It was a most beautiful instrument, and it was very remarkable that one should be able to see a fixed outline of a curve consisting of oscillations with periods of $\frac{1}{90}$th of a second.

With regard to Mr. Hunter's Paper, the author had referred to an automatic brush rocking gear on the Parsons turbine, and he, Mr. Lea, was looking forward to seeing that apparatus, because he was sure it would be extremely interesting, and he could not exactly understand how it worked. How the steam cylinder could control

(Mr. Henry Lea.)

the brush gear he was at a loss to imagine at present. Under the head of boiler feed-pumps, Mr. Hunter stated that in those pumps the steam was used expansively, and the cut-off could be regulated from the outside while the pumps were working, thus making them extremely economical as regards steam consumption. That required a little explanation. In the speaker's experience extremely economical steam consumption on the part of a single-cylinder direct-acting pump was something which was absolutely unknown. He was inclined to think it would be found that the consumption of steam with a pump of that description would be at the rate of probably not less than 100 lbs. of steam per H.P. per hour, and how that could be called an economical steam consumption he did not quite see.

Professor T. HUDSON BEARE, thought it would add greatly to the value of the Tables given on page 463, if Mr. Woodhouse would kindly say whether the figures given for the steam consumption were obtained by measurement from the discharge from the hot-well of the condenser, or whether they represented the quantity of water actually put into the boiler as measured by the Kennedy water meter. If the consumption of steam given (page 463) represented the actual feed into the boilers and included, therefore, all losses in the boilers, steam pipes, and the engines themselves, those results were simply marvellous. It was well known that there was always a very considerable difference between the weight of the actual feed into the boiler and that of the condensed steam which was delivered from the engine hot-well, especially with high-pressure steam, where these losses were generally quite imperceptible to the eye, but very appreciable when measured. The diagrams (page 459) seemed to show a very exceptional result for such a moderate amount of superheating; the dotted curve, which he imagined represented the theoretical adiabatic expansion curve for the measured quantity of steam used, coincided exactly with the actual high-pressure cylinder expansion curve; perhaps the author would be able to give some information as to how these diagrams were obtained, and what assumptions were made in drawing them. What he desired to know

was how the figures for use in the diagrams were obtained, and what were the data employed. With regard to Mr. Robinson's remarks (page 465), he agreed that the value of the Tables would be much enhanced if the results were given in terms of the heat-units supplied per horse-power per minute; the author had not given sufficient data in the Paper to enable any one to work them out. It was desirable also that the actual back-pressure of the low-pressure cylinder should be given as measured off the cards. It was very difficult, when superheated steam was used in an engine, to compare effectively the performance of one engine with another, unless the results were expressed in thermal units supplied per horse-power per minute or in some such form.

Sir Benjamin C. Browne thought it was well to mention one or two points, which would make more clear the history of the Newcastle companies and the works which the members were to visit. He was connected with the Newcastle and District Electric Light Co. as director, and when the companies were started he did not think the absolute necessity of having any condensation at all was sufficiently appreciated. When the site which Mr. Hopkinson described was chosen, the need of condensation was apparently not fully recognised. His experience was that it produced at once a very great economy, as had been so well described by Mr. Lea (page 467). The whole position was revolutionised, when the great demand for electric power as well as lighting was realised. When the company began, it looked to electric lighting as being the most important industry, but when it was found that large engine works were demanding power, the works of the company began to grow and expand very much, and that would explain the somewhat considerable changes of policy which would be seen in the sites.

Mr. Charles Hopkinson referred to the question as to whether the actual saving would not be decreased when the amount of water pumped increased, and said that the actual saving by having the turbines to use the return power would increase, but the percentage saved of the whole power would diminish because of the increased loss in the pipes.

2 L

(Mr. Charles Hopkinson.)

With regard to Mr. Woodhouse's Paper, the author had referred to the continuous test of the flue gases, and he would like to ask how the temperature changes were dealt with, so as to insure that the difference in weight of the sample should be a true measure of difference in density. In Fig. 3 (page 459) of Mr. Woodhouse's Paper diagrams were given, one at full load and the other at three-quarter load, and further on there was a comparison of the load and the efficiency of the various loads. He desired some explanation of what seemed to him a very serious effect on economy in those sets of figures. In the full load diagrams it would be found that the best vacuum on any part of the stroke was something like 9 lbs. and on the three-quarter load 12 lbs., and that was enough to make a big difference in the economy, and required some explanation. He also desired to be assured, for the satisfaction of those who did not know Mr. Merz and his staff, that in the progressive trials of economy, in which presumably the kilowatts had been measured by a watt-meter, that it had been calibrated at various loads.

A rather interesting point was to be found in Mr. Hunter's Paper in the Table (page 444) showing the turbine consumption. There it would be found, with the load practically steady, that the consumption bore a direct relation to the superheat, as would be expected. Taking the fourth line of the Table, it showed 19·1 lbs. of steam per kilowatt-hour, with a superheat of 132° F. At the bottom the steam was 17·73 lbs. per kilowatt-hour, with a superheat of 237° F., which meant that for 100° F. extra superheat about 15 per cent. of economy was obtained, and it took about 10 per cent. more work from the boilers to put that extra 100° in. Therefore the saving was really something like 5 per cent. in the actual economy of heat. In comparing that Table with the Table contained in Mr. Woodhouse's Paper (page 463), it would be seen that a reciprocating engine attained its greatest economy considerably below full load, and therefore, taking a particular case where it was desired to work with a margin of load, there was a substantial advantage in a reciprocating engine. In working at three-quarter load it had its maximum economy, and a certain demand for increased power was responded to without serious loss. The

Parsons turbine, if worked at three-quarter load, was working at a distinct disadvantage, and the greatest economy was only obtained when the emergency came on. Therefore the Parsons turbine would have the pull over the reciprocating engine in those cases in which it could be worked at its full load, and the variations could be put on to one of a number of sets. Where the whole of a variable load had to be taken by one prime motor, the reciprocating engine would have a very considerable advantage in economy. On page 445 the author referred to what was probably the most novel part of any of the installations which had been described—the new method of regulating the brush gear from a steam cylinder. He hoped that some further description of that would be given in the Proceedings when printed. It was said that it was controlled direct from the steam cylinder, but that was a little vague. Was it controlled by a man standing at the steam cylinder, or by pressure of steam, or by some mechanical means such as a governor?

Mr. G. Gerald Stoney said that he had been asked by Mr. Hunter to reply to one or two points, and he might say with regard to the tests of the 1,000-kilowatt turbo-generator that these were made at the Works of Messrs. C. A. Parsons and Co. exhausting into the Works condenser. The vacuum was bad, owing partly to the long length of the exhaust pipes and partly to the warmth of the cooling pond. At the Close Works an ample supply of cooling water was available from the river, and the condensers were close to the turbines, so that it should be quite possible to obtain the vacuum of 29 inches mentioned by Mr. Hunter, and the steam consumption would then be brought down to something like 16 lbs. per kilowatt-hour.

With regard to Mr. Hopkinson's question about the automatic brush gear, this was intended to shift automatically the brushes with change of load so as to secure sparkless commutation at all loads. The steam pressure at the inlet of a turbine was proportional to the load, and so was the lead of the brushes. If therefore a steam cylinder, having its piston controlled by a spring and connected to the brush rockers by suitable levers, was supplied with steam from

(Mr. G. Gerald Stoney.)

the inlet of the turbine, then as the load increased, the steam pressure at the inlet of the turbine increased, due to the action of the governor, and the piston in the cylinder was pushed up and the brushes were moved round the commutator to the non-sparking position. The general result of tests with superheated steam on turbines was to show a gain in economy of 1 per cent. for every 10° F. superheat. He thought Mr. Hunter was to be congratulated on having selected Mr. Ferranti's switch gear for his new station. In his opinion it was the best switch gear in the market for alternating work, and it should also be the best for continuous, as it was exceedingly simple and easy to work. He was glad Mr. Ferranti was now making continuous as well as alternating switch gear.

With regard to Mr. Woodhouse's Paper, he congratulated Mr. Andrew Laing on the result of his Wallsend Slipway engine, which was probably the record in steam consumption for any engine. The other engines, made by a well-known maker of marine engines on the Tyne, had given results from 25 to 30 per cent. worse than Mr. Laing's engine. There was one point, however, in reference to the steam consumption in turbines to which he thought attention should be drawn. At the Wallsend station, running the turbine in comparison to the reciprocating engines had been found to produce a saving of £5 per week in oil, which was equivalent to about 1,000 or 1,200 lbs. steam per hour. This on an average load of 600 kilowatts was equivalent to an extra consumption of 2 lbs. steam per kilowatt-hour. In the case of the turbine also the engine-room space was very much smaller. The turbine plant was the same length as the Wallsend Slipway engine and Thomson-Houston alternator, but half the width and half the height; that is, it occupied one quarter the cubical space for double the power, or the power per cubic foot of space was eight times as great in the turbine as in the case of the reciprocating engine and slow-speed alternator. This meant a much smaller and lower engine room, and also the foundations were much less, owing to there being no reciprocating parts.

Mr. Woodhouse said that the angular phase displacement with modern alternators should not exceed 6 degrees. This meant an irregularity factor of about 1–1300 for the reciprocating engines at Wallsend. He could hardly believe they had such a small irregularity factor as that, as it was possible to distinctly count the revolutions in his house, which was supplied off this station, by the flicker of the lights. He could always tell whether the turbine was running or not, because the turbine gave an absolutely steady light while the reciprocating engines did not. With regard to parallel running the turbine ran perfectly in parallel with the reciprocating engines, although with their large irregularity factors, amounting probably to 1 in 200, trouble might be expected. At Elberfeld the irregularity factor of the Sulzer engines was about 1 per cent., and the turbines ran perfectly in parallel. The turbine seemed to carry round the reciprocating engine through the bad part and was then driven by the engine at the other part of the revolution, and the general result was much steadier with the turbine in parallel than with the reciprocating engine alone. Another point about the turbine was that the steam consumption did not increase with time, while with most reciprocating engines, owing to the pistons and cylinders wearing and valves getting leaky, the consumption went up. They would be glad, if in two years' time the consumption of the Wallsend Slipway engine was taken and also that of the turbine.

Mr. WALTER DIXON said that the question of parallel running had been raised by Mr. Woodhouse. He would like to ask whether in the present station it was possible to run each and all of the alternators successfully in parallel.

Mr. W. L. SPENCE, speaking on Mr. Hopkinson's Paper, said the arrangement of motor-pump and turbine appeared at first sight to be an extremely pretty one, but there were certain points which he thought required explanation. The impeller of the pump is $23\frac{5}{8}$ inches, and that of the turbine is $13\frac{1}{2}$ inches, a difference of some 75 per cent. in diameter and peripheral velocity, but notwithstanding this the heads on

(Mr. W. L. Spence.)

the pump and turbine were stated—in the note under Fig. 5, Plate 49—to differ by only one foot or so. Such an extremely small line drop or loss of pressure in the uprising main, round numerous bends, through the condenser and probably four valves, and in the discharge pipe, was almost incredible. Was the one-foot drop a statement of accurately measured result or an estimate? In any case the discrepancy between pressure heads and peripheral velocities was exceedingly great, and it could only be accounted for by the inefficiency of the combination. Apart from this, however, did the result justify the complication? Obviously the maximum H.P. developed by the motor was not reduced, because the turbine could only come into operation after the pump had thrown its full volume of water up to and through the condensers without assistance. But it appeared that the normal duty of the motor was reduced some 42 per cent. below the figure at which it would stand unaided by the turbine. Would not this saving be almost reached without any complication, if the discharge pipe were treated as a siphon? Of course the temperature of the circulating water as it came from the condenser would prevent the full vacuum being reached, but probably 30 feet might be got, so that in this case the motor duty would be reduced say 32 per cent.

As to the motors, seeing that these were subject to quite abnormal load in starting, compound machines would appear to be better adapted for the purpose than the shunt ones used.

Regarding Mr. Woodhouse's Paper, electrical men would greatly like to know why a periodicity of 40 cycles per second was chosen. 40 was probably high enough to do a poor grade of lighting direct with alternating current, but the bulk of Mr. Woodhouse's lighting, if not all, was done by continuous current. For power purposes a lower frequency would have been better as conducing to slower speed motors, and it would have been very much better for direct current lighting, as rotary converters with the reduced initial cost and increased efficiency would have been practicable. He did not appreciate why motor generators should have been chosen—of course having a determination to generate at 40, and to distribute direct

current for lighting they followed as a matter of course, but as indicated his preference would be for 25 periods and rotary converters. His own experience with a combined lighting and power plant showed that rotary converters were entirely satisfactory at 23·4 periods.

He was quite at one with the author in aiming at perfect combustion in his boilers. That was a feature to which he had given special attention, and with dry-back boilers, air heating auxiliary and induced draught, a very fair degree of economy combined with smokelessness had been obtained in his plant at Alloa. Might he ask, from the point of view of obtaining a record of fact, whether the dynamos stated to have been manufactured by the British Thomson-Houston Co. were really so made, or were they merely supplied by this Company? Finally, the great emphasis laid by the author on the conditions of parallel running seemed to indicate that very great difficulties had been experienced. Were all sets regularly run in parallel?

Mr. Alfred Saxon asked Mr. Woodhouse whether the tests tabulated on Table 1 (page 463), with regard to the steam consumption at various loads, were all carried out under precisely the same conditions with regard to working jacketed or unjacketed, and also if superheated steam was used as he assumed. It was stated (page 458) with regard to the Wallsend Slipway and Engineering Co.'s three-crank triple-expansion engines when running at three-quarter load with superheated steam, that the efficiency was much the same with jacketed and unjacketed cylinders; at light loads the jacketing was advantageous. The results given in Table 1 (page 463) did not prove this statement, if the jackets were employed during these tests, because with a load of 364 I.H.P. the steam consumption was given as 10 lbs. per I.H.P., and with a load of 850 I.H.P. the steam consumption was given as 9·94 lbs. per I.H.P., which showed a slight gain in economy at the greater load. He would also like to know if any deduction was made for the condensed water drained from the jackets when they were used.

The PRESIDENT said there a great number of questions to be replied to, and he was rather loth to add to them, but he desired to put one question to Mr. Woodhouse, and that was whether in his experiments on the value of steam-jacketing, steam of the full boiler pressure was used in all the jackets, or whether any experiments were made on the use of a lower pressure in the jackets of the intermediate and low-pressure cylinders?

Mr. CHARLES HOPKINSON, in reply, said the only questions he could answer were those addressed from behind, which he heard but very imperfectly. He thought the principal point was a desire for information as to the difference in diameter of the pump and the turbine. One had to impart the energy to the water and the other had to take it out, so that they performed reverse functions. If there was an error of design the designers were absolved, because they did not know what pressure the turbine was going to work at. They knew what the levels of the water were going to be, but not the conditions of the pressure throughout, and they did not know it now, because the experiments were not completed so as to determine the best pressure to work at. It was obvious to everybody that the atmospheric pressure should be used, as it lessened the head against which the pump had to work. The head available for the turbine would be the head of the water less the atmospheric head, and the makers had had to conceive that they might not have more than 60 feet of head on the turbine. On the other hand, if the water was pumped through the turbine and there was a pressure all through, as at times had been done with a certain amount of advantage, there might be obtained at the turbine something like 45 lbs. pressure, equal to nearly 100 feet of head. Therefore the conditions were somewhat uncertain. The experimental results as to saving were borne out by the results in the pump-house; if the turbine was shut down, the motors had rather more than they could do, but if the turbines were kept running, everything went smoothly; so that whether the design was right or wrong it did its work fairly well.

Mr. W. D. Hunter, in reply, said he had not the figures of the heat-units associated with the test, and feared it would not be possible with the data in his possession to work out the thermal efficiency of the generator in the way Mr. Robinson desired (page 465); if the figures could be arrived at, he would be pleased to work them out, and hand them to the Secretary, to be embodied in the Proceedings. With regard to the feed-pumps, he thought the economy of the Weir pump was best shown, if the results were expressed in lbs. of water delivered at the boiler per lb. of steam used.

Mr. W. B. Woodhouse said that in all steam consumption tests the air-pump discharge was weighed, the jacket drains being weighed separately. The Kennedy water meter, referred to in the Paper, was used in boiler tests. With regard to the test of the Slipway engine in Table 1 (page 463), this was made previous to that of Table 2 and with a better vacuum; the combined cards, as pointed out by Professor Beare, showed dry steam in the H.P. cylinder. At light loads the cards were still more interesting, as showing the benefit of jacketing.

In answer to Professor Lineham (page 465), the steam consumption of the turbine per kilowatt-hour steadily increased as the load decreased, at half load being 21 lbs.; below half load the increase was more rapid. A curve was given, Fig. 7 (page 478), showing the steam consumption at various loads.

With reference to the four-crank engines the steam consumption was slightly higher; the figures of the Wallsend Slipway engine test were published as being more interesting.

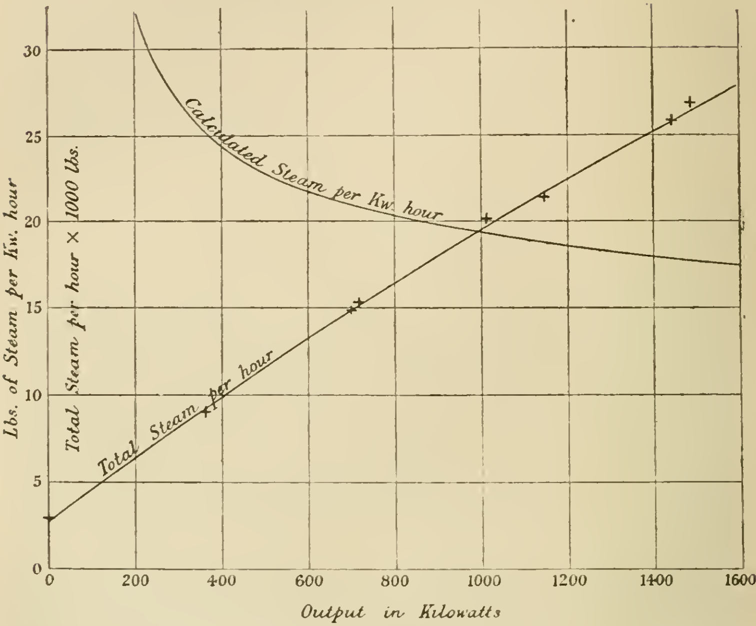
In answer to Mr. Spence (page 474), the lighting of some outlying districts was by alternating current, and a frequency of 40 cycles was taken as being the lowest at which lighting was possible; the frequency being decided, it followed that motor generators should be installed. With a system such as that of the Newcastle Supply Co., where there was a number of large motors being started and stopped at all times, he thought that there would have been trouble with the hunting of rotaries. All the three-phase generators ran well in parallel, there

(Mr. W. B. Woodhouse.)

FIG. 7.

Steam-consumption test of 1,500 Kw. Turbo-Alternator.

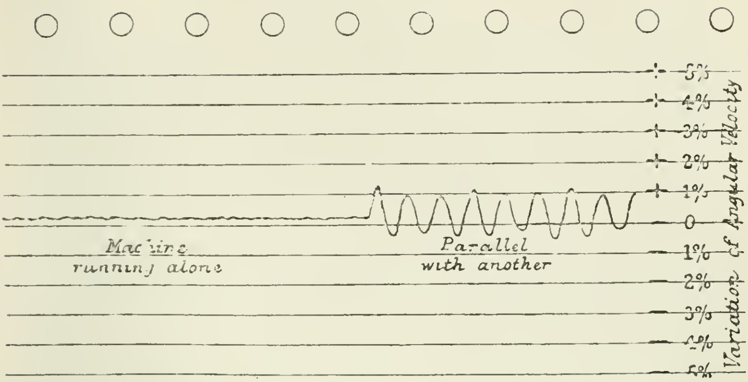
(Parsons.) 8th June 1902.



being no noticeable difference between the three- and four-crank engines. The engines needed adjustment in the first place, but he understood that this was the experience of everyone with regard to alternators.

The Tachograph was useful in making adjustments, and showed clearly that if an engine had an irregularity of crank effort, the paralleling with another engine emphasized the irregularity of both engines; this was due to the fact that when one alternator was behind the cophasal position, the torque of that engine was greater than the mean and was accelerating the rotating masses, and *vice versâ;* the synchronising force acted in the same direction and increased the irregularity. Fig. 8 (page 479) was a record taken to show this. Mr. Lea had suggested the use of the oscillograph for observing the irregularity. He had never seen the oscillograph used for this

FIG. 8.
Tachograph Record.



purpose; it would of course require a source of steady speed to which the varying speed could be compared. Mr. Stoney's figures (page 472) of the space occupied by the turbine neglected the fact that the air pump and condenser took up as much room as the turbine itself, and needed a deep basement. The saving in oil also was not so great, under ordinary running conditions, as he had stated.

As regards the irregularity factor, a close specification was needed, due to the fact pointed out above. In answer to Mr. Hopkinson (page 471), the pipe leading from the flue to the econometer was laid on the outside of the flue walls with a filtering and drying arrangement, so that by the time the gases reached the instrument, they were practically at the temperature of the surrounding air.

In answer to the President (page 476), the jacket pressures were reduced in the Slipway engine to about 40 lbs. per square inch for the M.P. cylinder and 12 lbs. per square inch for the L.P. No tests had been made with other pressures. The test of the engine with and without jackets was made at three-quarter load; the difference in efficiency being so small as to be within the limits of errors of observation.

Communication.

Mr. C. HUMPHREY WINGFIELD wrote that he thought at first sight Mr. Hopkinson had been attempting to drive a pump by a turbine supplied by the said pump—formerly a very favourite scheme for procuring "perpetual motion," or power for nothing! On looking more closely into the matter, however, he found he had made what might, under such unusual conditions as having to pump circulating water against a vertical head of 86 feet, prove a really valuable improvement. Where the lift was within the limit of a barometric column (say under 30 feet of water) he did not think any gain would ensue from the addition of a turbine—rather the reverse from frictional and eddy losses. Under these circumstances, if the discharge pipe was under water the whole system acted like a syphon, and the pump only had to hurry the flow of water; except when an accumulation of air took place, when, for a few minutes, the pump might have to work against the whole head in order to expel it through a pet cock.

Where the head was greater than the barometric column, however, the difference between it and say 30 feet was available for working the turbine, and was (after deducting the losses mentioned in the last lines of the Paper) a clear gain which the author was to be congratulated on having made use of.

Would the author add a section of the centrifugal pump? The drawing appeared to show that the water entered at one side, which did not agree with the description (page 438). He would also like to know whether experiments had been made with and without the "guide rings of special construction," demonstrating its utility?

With the delivery in a radial position as shown, it was not improbable that a gain might follow from stopping the spin of the water in the casing, but unless the latter were much larger than shown, he thought it likely that this could be done only at the expense of losses due to eddy currents which would greatly reduce the proportion of the kinetic energy converted into pressure head. In casing of moderate dimensions the usual "Gwynne" form of pump with tangential delivery was hard to beat.

Would the author give fuller details of the trials in which the suction and delivery pipes were throttled? If a centrifugal pump, running at a certain speed delivered x gallons of water per hour through a given delivery pipe, the writer thought it would not deliver anything like the same amount if the pipe were shortened and the pressure in the pump casing made the same as before by diminishing the aperture of discharge. Perhaps he had misunderstood the author's meaning however in this respect.

Mr. Hopkinson wrote explaining that the observations, from which the curves in Fig. 5, Plate 49, were derived, were from tests made at the manufacturers' works, and implied that the pipe line, condensers, and valves were not in the circuit. In reference to Mr. Wingfield's remarks (page 480), the water entered the revolving wheel axially on each side of the wheel, and the delivery was tangential, as stated in the Paper; and in the trials described, the pipes were the same in each case, and pressures observed were those on the pipe, not on the pump. Further illustrations of the turbine pump might be found in *Engineering* (vol. lxxiv, 18 July 1902, page 72), where a description was given of an installation in Spain.

SOME EXPERIMENTS ON STEAM-ENGINE ECONOMY.

By Professor R. L. WEIGHTON, of Newcastle-upon-Tyne.

The object of this Paper is to record the results of two separate and distinct sets of experiments bearing upon the economical performance of the Steam-Engine. The first constitutes a series of experiments, made with a view to determine the economical effect of reheating the steam passing through the receiver of a double expansion, or compound, engine. The second forms a series of experiments, made with a view to determine the influence upon economy, of degree of vacuum in the condenser of a triple-expansion engine. Both sets of experiments were made upon the experimental engines in the Engineering Laboratory at the Durham College of Science, Newcastle-upon-Tyne, and form part of a systematic course of research work upon the steam-engine, which is being carried out there.

The experiments will be dealt with in the order above mentioned.

I. Economical Effect of Receiver Reheating.

Method of Making the Trials.—The cylinders used for these trials were 7 inches and 15½ inches diameter, with a stroke of 18 inches. The boiler pressure was maintained constant throughout the trials at

200 lbs. per square inch above the atmosphere. The reheater, which was specially fitted to the engines for the purpose of these trials, was kindly lent by Messrs. Richardsons, Westgarth and Co., of Hartlepool Engine Works, and was fitted to the engines as shown in Plate 59. The heating surface consisted of a double coil of copper piping arranged inside a cast-iron chamber, and amounted to 30 square feet. The piping was $1\frac{1}{4}$ inch external diameter and 1·06 inch internal diameter. The receiver steam was compelled to pass through the heater by the blocking up of the middle cylinder and ports as indicated in the drawing. Steam of boiler pressure was admitted to the inside of the heater coils. The water condensed in these coils passed to a trap at a lower level, in which it was carefully measured, and from which it was periodically drained off, thus keeping the coils absolutely clear of water. The receiver condensation was similarly dealt with.

In order to test the effect of the reheating at different loads, the power of the engines was varied, and a progressive series of results was obtained. The power-variation was brought about by variation in the cut-off in the high-pressure cylinder, the low-pressure cut-off remaining constant throughout at 7 inches.

The engines are normally fitted with Meyer's expansion valves, but it so happened that prior to these trials, and for other purposes, the high-pressure cylinder had been fitted with a shifting eccentric, in imitation of the action of an automatic expansion governor. This eccentric was retained for the reheating trials, and was shifted by hand to give the variation in power. There was no governor attached to the engines. To preserve as great a uniformity of conditions as possible, the experiments were made in pairs, the only change between the two trials of each pair being, that in the one the steam was shut off from the reheater coils, while in the other the steam was admitted to the coils. Sufficient intervals were allowed to elapse between the trials to permit of the attainment of thermodynamic stability under the changed conditions. In this way only has the author found it possible to obtain consistent results in any series of experiments, where the differences in effect due to given changes in conditions are small.

The dynamometer was adjusted to give as nearly as possible 133 revolutions per minute for the first trial of a pair, the steam being shut off from the heater coils, and the receiver steam passing through the heater on its way to the low-pressure cylinder. Under these conditions a trial was run, and the observations and measurements recorded. Immediately on finishing, steam was admitted to the reheater coils, and the engines allowed to run till they adjusted themselves to the new conditions, no other change whatever being made as compared with the trial just completed. The vacuum was kept as nearly as possible constant throughout all the trials.

Results of the Trials.—The results are given in Table 1 (pages 492–493), and are recorded graphically in Fig. 2, Plate 60. Attention is directed to the following points in these results.

1. The amount of condensation per hour in the heater coils seems to be independent of the difference of temperature between the heating and the heated steam, and would appear to depend chiefly upon the quantity of heated steam (exhaust from high-pressure cylinder) passing through the heater in unit time. It will be noticed from the Table that as the power diminishes, so does the quantity condensed in the coils diminish, and this in spite of the fact that the temperature-difference increases as the power grows less.

2. The influence of the reheater is very marked in respect of the following, namely :—

(a) Reducing the amount of condensation in the receiver.

(b) Raising the receiver pressure.

(c) Raising the mean pressure throughout the engines.

(d) Increasing the speed of revolution of the engines.

(e) Increasing the dryness of the steam acting in the low-pressure cylinder.

These may be ranked as effects which are in themselves favourable to the attainment of economy.

3. The influence of the reheater is, however, equally marked in effects which are detrimental to economy, namely :—

(a) Lowering the mechanical efficiency of the engines.

(b) Increasing the steam consumption per horse-power developed.

From the last two columns of Table 1 (page 493), it is seen that at all powers there is a slight loss attendant on the use of the reheater, with the single exception of "water per I.H.P.," Trial X.

The consumption per B.H.P. is in all cases consistently greater when the heater is in use, the average increase being 2·6 per cent. against the heater. The economic effect of the heater in terms of water per I.H.P. is exceedingly small, an average of 0·18 per cent. against the heater. The smallness here, however, is entirely due to Trial X already referred to. The effect, at any rate in terms of brake horse-power, is appreciable and definite, and this effect—as compared with that in terms of indicated horse-power—is almost entirely due to the detrimental influence of the reheater upon mechanical efficiency. It will be noticed from the Table that in every case a lessened mechanical efficiency is associated with the use of the reheater, the average adverse effect being 2·2 per cent. The cause of this very undesirable effect is doubtless to be found in the greater dryness of the working steam after passing through the reheater, when steam is in the coils. The result here obtained shows the necessity for stating steam-engine efficiency in terms of brake horse-power, instead of indicated horse-power, especially in those cases in which steam-drying arrangements or devices are employed, for example, steam jackets, superheaters, &c.

II. Economical Effect of Degree of Vacuum.

Method of Making the Trials.—For these trials the cylinders were arranged as triple-expansion, having diameters of 7, $10\frac{1}{2}$, $15\frac{1}{2}$ inches with 18 inches stroke. The boiler pressure employed was 150 lbs. above the atmosphere, and the cut-off in each cylinder was retained throughout at $10\frac{1}{2}$ inches. The brake adjustment was unchanged during the trials, so that any variation in speed of revolution of the engines was entirely due to variation in the vacuum. The degree of vacuum was the one and only condition which was varied throughout the trials, this variation being brought about by variation in the quantity of condensing water. Any degree of vacuum up to the

maximum was obtainable by this means. In the case of no vacuum at all, the air-pump was disconnected, and the feed-water simply allowed to run out into the measuring tanks, sufficient condensing water being supplied in this case to just prevent the pressure in the condenser from rising above that of the atmosphere.

The receivers were kept clear of water by drainage at intervals into the hot-well, and it is owing to this drainage that the hot-well temperature was slightly in excess of the temperature corresponding to the condenser vacuum.

Results of the Trials.—The general results are given in Table 2, (pages 494–495), and are recorded, after reduction, in Fig. 3, Plate 60. All the results on this diagram are plotted to a base of degree of vacuum. It is therefore necessary they should first be reduced to some constant speed of revolution. The revolutions chosen for this purpose are 120 per minute.

Curve W_1 gives the pounds of water (that is, steam) used per hour (as measured) on this basis.

Curve W_H gives this water expressed in terms of British Thermal Units expended between the high-pressure steam-chest and the hot-well.

Curves I and E show respectively the indicated horse-power and the brake horse-power, both reduced to the basis of 120 revolutions.

Curve M indicates the mean-pressure referred to the low-pressure cylinder as given by the indicator cards.

Curve R shows the variation of revolutions per minute due to variation in vacuum.

If the variation in hot-well temperature be disregarded, curve W_1 gives the steam consumption, and the ordinates of this curve, divided by the corresponding ordinates of curve E, will give the pounds of water used per brake horse-power per hour, as shown in curve ω_I. This curve attains its lowest point at from 26 to 28 inches of vacuum. Looked at in this way, therefore, the highest vacuum is practically also the most economical vacuum, although it does not appear that there is any gain by going higher than 26 inches vacuum. This however, does not give

the true economy of the engines, because the feed-water in the case of the lower vacua would carry away from the engines—and presumably to the boilers—a greater quantity of heat per pound than would be the case with the higher vacua. Hence the need for curve W_H, the ordinates of which, divided by those of curve E, result in curve ω_H, which curve represents the true economical performance, namely, heat-units expended per brake horse-power developed, expressed in pounds of water for convenience in comparison. It will be noted that curve ω_H attains its lowest point at or about 20 inches of vacuum. So far as degree of vacuum affects economy, therefore, it follows that these engines were working with the minimum expenditure of heat units—or, to put it otherwise, coal—per useful horse-power developed, when the vacuum carried amounted to 20 inches.

It is not by any means an uncommon opinion amongst engineers that the highest economy is associated with the highest possible vacuum. This opinion is probably based upon two suppositions, first, that the aggregate mean-pressure in the cylinders rises and falls —other things equal—in proportion as the vacuum rises and falls; and second, that the steam consumption per revolution is—other things equal—not affected by the vacuum. On these suppositions any addition to the vacuum would mean the same addition to the mean-pressure, without any addition to the steam consumption. How far the first supposition is from the truth will be seen by comparing curves M and M_1. M_1 is a straight line passing through the point representing mean-pressure at zero vacuum, which from the Table is seen to be 29·75. The ordinates to M_1 simply are 29·75 + vacuum in pounds per square inch; and this line would represent the mean pressure if the lower condenser temperatures associated with the higher vacua had no condensing effect on the steam acting in the cylinders. Curve M represents the actual mean-pressure realized, and the vertical distance between M and M_1 at any vacuum shows the loss due to cooling effect of the condenser at that vacuum. It is seen that the loss grows as the vacuum rises.

How far the second supposition is from the truth is indicated by the upward inclination of curve W_1. This curve virtually represents

the water used per revolution at the various vacua, because it represents it at constant revolutions, and the fact that it inclines upwards shows that more steam enters the high-pressure cylinder per stroke at a high vacuum than at a low vacuum. This can only mean that the cooling or condensing effect of the condenser temperature is felt throughout the cylinders even as far as the high-pressure admission. Had the vacuum no effect upon the weight of steam admitted per stroke into the high-pressure cylinder, curve W_1 would simply be a horizontal straight line.

The indicator cards, as well as the recorded receiver pressures, show this fact in another way. Specimen indicator cards are given in Fig. 4 (page 490), from which it will be seen how the high-pressure exhaust "sympathizes" with that of the low-pressure, and how the steam line, as well as the exhaust line of the intermediate cards, follow suit. In connection with all this, it is to be borne in mind that no adjustment or condition about the engines was altered during the trials, with the single exception of the amount of condensing water. All the variation in results must therefore be due to this single cause. Mechanical efficiency does not appear to be materially affected by degree of vacuum. Partly for this reason, and partly in order to avoid confusion in the diagram, the curve of water used per I.H.P. in terms of W_H has not been drawn. It is to all intents and purposes parallel with that for B.H.P. but occupying a lower position on the diagram.

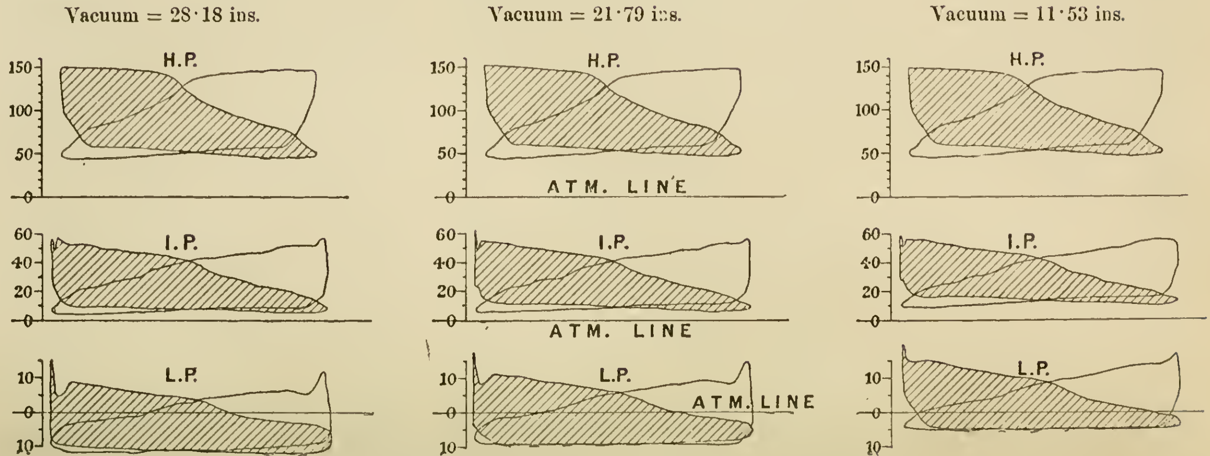
These experiments have been made on triple-expansion engines. The question naturally arises, would similar results follow from experiments on double and quadruple expansion? A thoroughly conclusive answer to such a question can only be obtained by direct tests, and such will probably be carried out later on, with these engines. Certain predictions from the foregoing results may however fairly be hazarded. The fewer the number of cylinders intervening between the steam-pipe and the condenser the greater would be the general effect of the condenser temperature upon the working steam in the cylinders; and *vice versa*, the greater the number of cylinders the less would be the condenser effect upon this steam. It may therefore be expected that, in a two-cylinder compound

Fig. 4.

Samples of Indicator Cards at Three Different Degrees of Vacuum.

Cylinders 7 ins., 10¼ ins., 15½ ins. Stroke 18 ins. Cut off 10½ ins. in each Cylinder.

(Nothing changed except vacuum.)



engine, the vacuum associated with maximum economy will be somewhat less than 20 inches, while in the case of a four-cylinder quadruple-expansion engine, the corresponding vacuum will be somewhat higher than 20 inches. During the whole of these trials steam was shut off from the cylinder jackets. How far the results may be modified—if at all—by the use of jackets will be subject of future tests.

The Paper is illustrated by Plates 59 and 60 and 1 Fig. in letterpress.

TABLE 1 *(continued on opposite page)*.

Results of Receiver

Cylinders $\frac{7'' \text{ and } 15\frac{1}{2}''}{18''}$. Boiler Pressure 200 lbs. (above atm.)

Power varied by shifting H.P. Eccentric. Condensing

No. of Trial	I	II	III
Date of Trial. 1900	May 4	May 4	April 27
Reheater Steam . . . off or on	off	on	off
Shift of H.P. Eccentric . . inches	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{4}$
Pressure in H.P. Steam Chest lbs. above atm.	195·5	194	197
Pressure in Reheater Coils „ „ „	0	193	0
Pressure in Receiver . „ „ „	50	54·3	43
Barometer . . inches of mercury	29·4	29·4	30
Vacuum . . „ „ „	23·12	23	24·4
Mean Pressure, reduced to L.P. Cylinder lbs. per sq. inch	58·1	60·4	54
Revolutions per minute	133·4	136·1	130·2
Condensation in Receiver lbs. per hour	95	49·5	not taken
Condensation in Coils of Reheater lbs. per hour	0	110	0
Total Water used . lbs. per hour, W	2298	2454	2050
Steam shown by Indicator Cards at L.P. cut-off in percentage of total water	72	76·7	68·4
Indicated Horse-Power	131	138·8	118·7
Brake Horse-Power	120·3	126·1	112·6
Mechanical Efficiency	·918	·908	·948
Pounds Water . . per I.H.P. hour	17·54	17·61	17·2
Pounds Water . . „ B.H.P. „	19·1	19·46	18·2

NOTES.—1. Trials were made in *pairs*—steam *off* and steam *on*

2. The Brake Sluices were adjusted for the first of each

3. In plotting the results on Fig. 2, Plate 60, the Powers in Nos. I and

(*concluded from opposite page*) TABLE 1.

Reheating Trials.

Jacket Steam-off. Cut-off in L.P. Cylinder 7 inches.

Water adjusted for an approximate Vacuum of 24·4 inches.

IV	V	VI	VII	VIII	IX	X
April 27	May 11	May 11	May 18	May 18	May 25	May 25
on	off	on	off	on	off	on
$\frac{1}{4}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{5}{8}$
196	198	197	199	198	198	198
194	0	194	0	195	0	195
47·5	31	36	16·7	21	1·0	.4
30	29·8	29·8	29·9	29·9	29·75	29·75
24·37	24·4	24·5	24·42	24·45	24·2	24·4
55·6	44	46·5	30·8	32·7	12·36	13·78
134·4	132·8	137·6	133·9	137·5	136·4	143·2
not taken	81·78	43·96	55·8	32·6	would not drain	would not drain
106	0	88	0	68	0	22
2216	1725	1896	1270·6	1378·6	599·5	686
75	68·3	77·2	60	70	60·4	71
126·2	98·7	107·6	69·7	75	28·5	33·3
117·1	94·1	99·5	63·5	67·7	24·3	27·32
·928	·953	·925	·911	·902	·854	·820
17·5	17·5	17·62	18·23	18·38	21·06	20·59
18·92	18·33	19·06	20	20·36	24·67	25·11

Reheater—the one after the other with a sufficient interval.

pair, and were not altered for the second trial of the pair.

II, are brought up to the average vacuum of the others, viz., 24·4 inches.

TABLE 2 (*continued on opposite page*).

Results of Variable

Cylinders $\frac{7''-10\frac{1}{2}''-15\frac{1}{2}''}{18''}$. Jacket Steam off.

Cut-off in each Cylinder $10\frac{1}{2}$ inches.

No. of Trial	I	II	III
Date of Trial. 1902	Mar. 14	Feb. 28	Feb. 28
Vacuum—inches of mercury	0	11·53	16·70
$\frac{\text{Condensing Water}}{\text{Feed Water}}$	—	5·7	7·0
Barometer	29·7	29·15	29·15
Pressure in H.P. Steam Chest (above atm.)	147	146	147
Revolutions per minute. (R)	109	118·6	122·6
Indicated Horse-Power	54·7	70·2	76·9
Brake Horse Power	48·3	60·3	64·9
Mechanical Efficiency	·882	·859	·844
Total Water used per hour in pounds. (W)	1048	1141·5	1189·5
Hot-well Temperature °Fahr. (t_H)	212	193	177
Mean Pressure reduced to Low-pressure Cylinder (M)	29·75	35·06	37·13
I.H.P. at 120 Revolutions. (I)	60·3	71	75·2
B.H.P. at 120 Revolutions. (E)	53·2	61	63·5
Water per Hour at 120 Revolutions. $(W_1) = \frac{120\ W}{R}$	1154	1155	1164
Heat Units per Hour at 120 Revolutions* $(W_H) = \frac{W_1 (T_1 - t_H)}{T_1}$	954	973	996

* T_1 = Total heat—above zero Fahr.—per lb. of steam of boiler-pressure. (W_H) = Heat units reduced to lbs. of water for comparison.

(*concluded from opposite page*) TABLE 2.

Vacuum Trials.

Receivers drained continuously.

Brake Sluices shut 1 inch.

IV	V	VI	VII	VIII	IX
Feb. 28	Mar. 7	Feb. 21	Feb. 21	Feb. 21	Feb. 21
19·69	20·40	21·79	24·07	25·72	28·18
8·4	8·3	8·7	11·2	15·3	43·7
29·15	29·7	29·85	29·85	29·85	29·85
148	147	151	150	148	149
124·5	124·3	125·4	126·6	127	127
78·7	78·5	81	83	82·2	83·4
67·4	66·9	69·1	70·6	71·1	71·5
·856	·852	·853	·850	·865	·857
1210	1218	1217	1235	1246	1247
164·5	164·3	157	142·8	129·2	88·8
37·41	37·33	38·22	38·85	38·32	38·85
75·8	75·7	77·5	78·7	77·6	78·8
65	64·6	66·1	67	67·2	67·6
1166	1175	1164	1170	1177	1178
1008	1016	1015	1033	1053	1092

Discussion.

The PRESIDENT said the Paper must be regarded from two standpoints, first as a record of carefully conducted experiments, and secondly as an account of deductions made from those experiments. From both those standpoints the Paper had very great value, and he asked the members by acclamation to record their thanks to Professor Weighton for bringing it before them.

Professor T. HUDSON BEARE said that unfortunately he had only had an opportunity of seeing the Paper for the first time that morning, and had not been able to read it through before. He could not venture to criticise such a piece of original work without a very careful study of the Paper, and a comparison of the results obtained with those obtained by himself and others in similar experiments. Any remarks, therefore, that he had to offer he would make in the form of a written communication later on; he merely desired now to thank Professor Weighton for his most admirable communication. He knew from long experience what an immense amount of labour and trouble experiments of this nature meant to the experimenter, and the results given in the Paper represented probably only a very small portion of the labour thrown upon the author in carrying out this research. He complimented the author on the extreme clearness with which everything had been put and the full information given both as to the nature of the experiments, and the observations made, and also as to the methods of eliminating possible errors of observation and checking and comparing one result with another. He was sure that everything necessary for reference purposes had been given in the Paper, and that the experiments would be of the utmost value in the future to all users and designers of steam-engines. Professor Weighton had been long known for the excellent original work he had been doing on the subject of the economy of steam-engines and the influence of the various factors upon that economy.

The two particular lines he had taken up in this research—the influence of the reheater and the influence of the vacuum—were two matters of great importance at the present day. In America so much attention had lately been given to the employment of reheaters, that it was extremely interesting to have the striking quantitative results given in this Paper. He had been considerably surprised to find that the steam used per B.H.P. hour had not been reduced by the use of a reheater, but had actually increased in the particular series of experiments carried out by the author. The question of the influence of the vacuum on the economy of marine and other engines had been touched upon by himself, in the summary he had prepared of the marine-engine trials carried out by a Committee of the Institution some years ago. He would have great interest in looking again over the results he then gave and the conclusions he drew, and comparing them with the results obtained by the author. He could only say in conclusion that the thanks of the whole Institution, and of all engineers, would be given to Professor Weighton for these experiments and the manner in which he had placed them before the Institution.

Mr. MARK ROBINSON, Member of Council, was sure that steam engineers had not had before them for a long time past any Paper more valuable and more interesting than Professor Weighton's, and he regretted he had not had time to study it as it deserved. A few points, however, attracted notice at once. There was a very large volume ratio between the high-pressure and the low-pressure cylinders, due to the engine being triple-expansion with the middle cylinder cut out; it therefore came well into comparison with the recent American compound engines with very large cylinder ratios, and with reheaters. The cut-off was given as seven inches out of eighteen in the low-pressure cylinder. That seemed to be a very early cut-off for the low-pressure cylinder, but he had not had an opportunity of working out its probable thermal effect on the results. The first result to be noted was that the condensation in the reheating coil did not vary with the difference of temperature between the reheating steam and the reheated steam, but depended

(Mr. Mark Robinson.)

practically upon the quantity of steam being dealt with. This was quite in accordance with experiments carried out by the late Mr. Willans; the number of molecules in the reheater, striking per unit of time against the hot tube which had to reheat them, was clearly an element in the calculation of the amount of heat which might be expected to be carried away from the reheater. That reheating lowered the mechanical efficiency of the engine was quite to be expected, because there would be less water-lubrication in the low-pressure cylinder, but he would not have expected that this would produce so relatively enormous a falling off as 2·2 per cent. in the brake efficiency.

With regard to the connection between steam economy and the degree of vacuum, that had been a favourite subject of the late Mr. Willans. Mr. Willans began with almost exactly the figures the author had arrived at; he had his best results with a 20-inch vacuum. But that was in the day of the early Willans launch-engine, the thermal efficiency of which was comparatively low; when it was replaced by the thermally very perfect Central-Valve Engine the result was quite different. Trials with the latter engine proved that within reasonable limits better results were obtained per I.H.P. for every improvement of the vacuum, certainly up to 27 inches. In fact they had been able to establish a very convenient law for the Willans engine, if not for others, namely, that each inch of vacuum corresponded with about 1 per cent. of steam consumption (per I.H.P.). Thus with 27 inches, the consumption would be roughly about 7 per cent. better than with 20 inches, and so on. The saving per brake horse-power was of course less, but it by no means disappeared altogether. Had Professor Weighton's engine been re-designed between the trials with smaller cylinders, to correspond with the lessened expansion of the steam with lower vacuum, he could have better understood some of the differences in the brake efficiency, for smaller cylinders and smaller piston-rings would naturally mean lessened friction loss. But in the present case it was always the same engine, and nothing was altered but the vacuum, so that any serious change in the friction loss (not due to hammering caused by the disappearance of cushioning, which he understood

was not in question in the present instance) was scarcely intelligible to him. He could not help again remarking upon the great value of Papers of this kind, and upon the importance of such careful methods in dealing with steam-engine trials and efficiencies. Those responsible for the direction of the works with which he was connected felt so strongly upon this subject that they had spent some £30,000 in buildings and appliances for the efficient testing of steam-engines, and thousands of pounds yearly in carrying out such tests, and they did this in the belief, which he thought was justified, that knowledge was power. Yet if after years of experience there was one lesson which they had learned better than any other, it was the exceeding difficulty of carrying out a really satisfactory and reliable steam-engine trial. When he saw startling statements as to the remarkable economy of certain engines, they only led him to wish that the authors of them would carry out their trials as they could be carried out in a first-class testing-house, or, better, put them into the hands of a gentleman like Professor Weighton, not to say into the hands of a committee of gentlemen like Professor Weighton, before they published their startling figures. Professor Weighton and other engineers who worked on similar lines were doing a great service to the profession and to the steam-engine industry by bringing forward Papers such as this one, and he heartily wished he had had more time to study it, so that he could better express his appreciation of it.

Mr. CHARLES FORGAN said that he had had an opportunity of making similar experiments, and he certainly agreed with the effect of the reduced vacuum. At the Central London Railway Power-House they were running with 27 inches of vacuum, and by reducing it to 23 inches, the hot-wells were raised to about 133° F., thus obtaining a feed temperature, after passing through the economisers, of considerably over 200° F.; an increase of about 50° F. was effected, and by this nearly 40 tons of coal a week was saved.

Mr. Mark Robinson asked leave to add to his previous remarks that the value of a good vacuum depended, as the author had in fact pointed out, on the type of engine dealt with. With a simple engine and a fairly good pressure, he was sure there was no advantage in a high vacuum, because there was already an excessive range of temperature in the one cylinder. With a compound engine the total range of temperature might be profitably extended by lowering the temperature at discharge into the condenser, while with a triple-expansion engine the fullest range attainable, by discharging into a high vacuum, might still leave the range in each separate cylinder small enough to keep cylinder condensation within moderate limits. What troubled him was that the present experiments were actually made with a triple-expansion engine, which, according to his experience, ought not to show so great a sensitiveness to a moderate increase in the total range of temperature.

Professor W. H. Watkinson considered that some of the results of the reheating trials were somewhat surprising, but it should be noticed that the amount of reheating was very slight. The reheating surface in the reheater was not arranged in the most effective way for dealing with steam, and its area was only 30 square feet, so that roughly 78 lbs. of steam had to be dealt with for each square foot of surface in the reheater. As the steam discharged into the reheater was very wet, there could not possibly be any superheating due to the reheater, and in consequence it was not to be expected that there would be any gain in the efficiency. Without regenerative action the thermal efficiency of any heat engine cycle was reduced if any heat was supplied at a temperature lower than the maximum. In the case of the steam-engine it was probable that the thermodynamic loss due to reheating between the cylinders might be more than counterbalanced by the gain due to reduction of cylinder-wall action in both cylinders, providing the reheating was sufficient to completely dry or superheat the steam.

The only result of the reheater trials which he could not understand was the comparatively great reduction in the mechanical efficiency, and he thought that this must be due to some other cause

than the one suggested by the author. If the steam had been highly superheated, a definite change in the mechanical efficiency might have been expected, but there was no superheating of the steam, and the dryness fraction of the steam at cut-off in the low-pressure cylinder never exceeded 0·77. The steam was only rendered a little dryer by means of the reheater, and he should not have expected that that would cause a change of 2·2 per cent. in the mechanical efficiency of the engine. In the series of trials on the economical effect of the degree of vacuum, the quality of the steam probably varied as much as in the reheating trials, but in spite of this variation the mechanical efficiency, as stated (page 489), was not materially affected.

In connection with the vacuum trials it was interesting to note the great increase in the temperature range due to increase of vacuum. This increase in temperature range, for example, due to increasing the vacuum from 20·4 inches to 28·18 inches amounted to 75·5° F. To produce the same increase in temperature range by increasing the initial pressure of the steam, instead of by decreasing the vacuum, would have involved the raising of the initial pressure to about 400 lbs. per square inch. The thermal efficiency depended on the temperature range, and it was evident that the high vacuum method of increasing the thermal efficiency was more convenient than the high initial pressure method. With either method, in order to obtain the maximum resultant efficiency with such a great temperature range, some means must be employed to diminish condensation within the cylinders. If superheated steam had been used in the trials, it was probable that the maximum degree of vacuum would have given the maximum resultant efficiency. The curve ω_1, Fig. 3, Plate 60, showed that the weight of steam required per B.H.P.-hour was a minimum with about 27 inches of vacuum, and the curve ω_H showed that the heat required per B.H.P.-hour was a minimum when the vacuum was about 20 inches. This difference was due, as stated (page 488), to the higher temperature of the feed-water available with the lower vacuum. The conclusion to be drawn from these valuable results was that when economisers were used to heat the feed-water, the highest vacuum was practically the best, but in cases where these were not used a lower vacuum would give better results.

Mr. J. F. L. Crosland said the Paper gave much information upon matters which were under discussion in the "Engineer" newspaper thirty-five to forty years ago, when the question of the adoption of multicylinder engines was much debated. One of the principal reasons for the adoption of an additional cylinder, thereby converting a compound engine into a triple-expansion engine, was in order to avoid the effect of the vacuum temperature upon the steam admitted, and Professor Weighton was now giving some reasons for this addition. In one of his earliest experiences he (Mr. Crosland) introduced a feed-water heater between the low-pressure cylinder and the condenser, which gave an advantage in respect to the temperature of the feed-water, and it appeared that the consequent slight reduction in the vacuum was not attended with any disadvantage, which now appeared to be confirmed by the Professor's experiments. With regard to the question of intermediate reheating of the steam, he was of opinion that the heater adopted should have been larger, and it would have been all the better, if it had been capable of imparting some amount of superheat to the steam on its way from the high-pressure to the low-pressure cylinder. It appeared also from the arrangements of the heater, that the first half of the pipe must be at all times filled with water, through which the steam must pass in bubbles on its way to the second half of the coil. Of course if steam were passing in large quantities, it would blow the water through as fast as formed, but the highest amount of steam passed is only 110 lbs. per hour, which would be quite unable to effect this result. The Paper was a very useful one, as drawing attention to two important points which it was hoped might receive further attention.

Mr. Alfred Saxon thought it might be taken for granted that the results the author had arrived at were typical of the particular engines experimented upon, and too much stress must not be laid upon their general application. It would be a fatal mistake for engine designers and builders not to put in the most perfect condensing apparatus, and to design their low-pressure cylinders and other accessories which enabled a good vacuum to be reached, because of the particular results obtained in these experimental

engines. If it was found to be more economical in practice to work engines at a reduced vacuum, this could be very easily seen to by the engine builder and instructions given to the engine attendant, who had ample opportunities of testing the best vacuum at which any particular engine under his charge would run. It appeared to him that the amount of steam passing through the cylinders should influence and ought to determine the amount of vacuum that was economical and desirable. In designing an engine it was important under any circumstances to be able to get the utmost power out of it, and the engine was on the whole more valuable to its purchaser the more powerful it was. The Paper clearly showed that an improved vacuum brought out the highest power, although it did not appear to bring out the highest mechanical efficiency. He was very sorry indeed that the engines were not fitted with a high-pressure cylinder with an automatic cut-off, so that the same initial steam-pressure on the piston might have been used without causing increase of speed during the tests. He thought it would have been found, despite the results of the experiments, as they were carried out, that an earlier cut-off in the high-pressure cylinder would have been obtained with the higher vacuum instead of an increase of speed, if the engine had been kept worked at a constant speed with the same pressure on the piston, and driving a fixed load throughout the experiments. He wished to know why, in the case of the compound engine, the author used steam of 200 lbs. pressure, and in the case of the triple-expansion engine 150 lbs. His experience did not coincide with Mr. Mark Robinson's, because he considered the cut-off used in the compound engine trials sufficiently early, though he considered it too late with the low-pressure cylinder of the triple. He thought a better result would have been arrived at with 200 lbs. pressure, if a cut-off at half-stroke had been adopted in that cylinder, and it was rather a pity that in connection with these experiments a variation was not made in the point of cut-off with the various differences in vacuum. If an earlier cut-off had been used in the low-pressure cylinder, the steam would have been expanded down to a lower terminal pressure before being affected by the vacuum in the condenser. The evidence was strongly in favour

(Mr. Alfred Saxon.)

of an engine being designed so as to produce the highest vacuum obtainable, and that the injection water should be reduced to suit the load the engine was to work at; and that was found to be the most economical point in practice. In connection with textile mill practice, a very great variation in the temperature of the injection water available was found, and sometimes the temperature of the water in the lodge or cooling pond became so high that a very moderate vacuum was only obtained towards the week-end. In connection with some four-cylinder triple-expansion engines that his firm had put down, he found that the attendant was using a higher vacuum on one of the two sets of condensing apparatus, which affected the low-pressure cylinder on that particular side, and using two or three inches lower vacuum on the side where the boiler pump was fed from; the attendant told him that after considerable experiment he had found this system of working to give the best results. That seemed to prove that when the boiler-feed was not taken into account, a higher vacuum was advantageous.

Referring to the statement (page 487), "This, however, does not give the true economy of the engines, because the feed-water in the case of the lower vacua would carry away from the engines—and presumably to the boilers—a greater quantity of heat per pound than would be the case with the higher vacua." In this connection it must be taken into account that in ordinary jet condensing engines, such as are generally used in land practice, the proportion of water utilized for boiler-feed was but a small proportion of the total amount of water used for condensing purposes, so the benefit derived from the extra quantity of heat, owing to the lower vacuum, would not be nearly so great as the author seemed to consider to be the case.

Mr. Druitt Halpin said that the intermediate receiver between two cylinders which enabled the cranks to work at right angles was invented by the late Mr. Cowper, who was the inventor of tho reheating, the whole subject then being familiarly known as the "hot-pot." Some 35 or 40 years ago Mr. Cowper himself carried out a large number of experiments on that particular point, and they

quite tallied with what the author had now given in his Paper. Mr. Cowper could not get any good at all out of the reheating, and could not produce an economical effect, and that was the reason that caused him to give it up, although the intermediate receiver was retained.

Mr. William P. Digby, while sharing in the admiration which every speaker had expressed for the Paper, also shared Professor Beare's surprise that so apparently desirable an adjunct to a steam-engine as a reheater had not resulted in a saving of the water required per B.H.P. in the engine. He suggested that fresh reheater experiments might be carried out with all the steam circulating around the reheater being superheated previous to its use, or the steam on leaving the high-pressure cylinder passing through a coil placed in the flues to dry the steam before it was used in the low-pressure cylinder. That suggestion was made with the view that, if the steam was reheated before its use in the low-pressure cylinder, it should be reheated if possible without a further consumption of coal by the evaporation of extra water within the boiler, that is, the reheating of the steam should be carried out by utilising the escaping furnace-gases.

The President said that perhaps Professor Weighton in replying would inform the members as to the arrangement for lubricating the cylinders, which might have some influence on the mechanical efficiency. He supposed the same arrangement was used throughout the trials with the reheater in use and without it.

Professor Weighton, in reply, said that with regard to the reheating trials, perhaps he ought to have mentioned that the object with which they were undertaken was to try and prove conclusively whether the current American practice in large land engines was correct. Two years ago he paid a visit to the United States and went through the country examining engineering practice, chiefly that type of engine applied to generate electric current in large quantities, and he found the Americans were

(Professor Weighton.)

building their large engines with enormous reheaters behind the cylinders, which looked almost like subsidiary boilers. In Milwaukee he had a long interview with Mr. Reynolds, than whom he was given to understand there was no man in America knew more about steam engineering. One question he asked Mr. Reynolds was what saving he obtained from the use of the reheater. Mr. Reynolds said he had been asked so often that he was tired of answering the question. He said that as a matter of fact he could not tell whether he got any saving or not, but it was the fashion to put them on. When Professor Weighton came home, he determined to try and elucidate the question. The size of the reheater which he used was considerably greater than the proportion adopted by the Americans, his object being to test the American practice, and he thought he would err on the safe side and give the reheater plenty of surface. If Professor Watkinson would look into the surface employed in the reheaters of the American engines in Glasgow generating the electric current for the tramways, he would find the proportion adopted here greater than in those American engines. He did not approach the subject from the point of view of determining what was the best size of the reheater or what was the best way of reheating, such as the last speaker had indicated, by means of waste gases; he wanted to prove whether the current American practice had anything in it or not, and he submitted that the experiments showed, as far as experiments could show, that there was not anything in it—that there was less than something in it.

With regard to Mr. Mark Robinson's remarks (page 497), the large ratio of cylinders was partly due to the fact that he could not change the ratio very well, and partly to the fact that for high pressures a large ratio was necessary, and further the American practice was a large ratio and high pressure. Those engines were in the compound form fairly representative of American practice, and fairly representative of what was the best ratio for the pressure they were used at. He did not think there was anything to be said from the point of view of the ratio of the cylinders. Mr. Robinson mentioned that he considered the low-pressure cut-off too early. When he was reading the Paper, he mentioned that that

cut-off at 7 inches out of a stroke of 18 inches was purposely adopted as being the best. Some might wonder how he knew it was the best. He made a very long series of experiments which were the subject of a Paper read a couple of years ago before the North-East Coast Institution of Engineers and Shipbuilders, and those experiments demonstrated that 7 inches was about the best cut-off for cylinders of the given ratio. It had no significance relatively, so long as it was kept constant, and he might have adopted another cut-off. The results were comparative, not absolute, and therefore any reasonable cut-off would be as good as another; but he adopted the 7 inches because associated with that cut-off was the highest economy so far as the low-pressure cylinder cut-off could determine economy. Another speaker had raised that question and the question of $10\frac{1}{2}$ inches cut-off throughout in the vacuum trials, and said he thought that was too late, believing that an earlier cut-off would give a better result. That showed that the speaker was not appreciating what was being aimed at in the experiments. He was not aiming at getting a good result at all, and did not want a good result; there was no purpose in getting a good result. He wanted to get at the truth, whether good or bad. It so happened however that in those engines, working as triple expansion, with the ratios of cylinders given, and at 150 lbs. pressure, $10\frac{1}{2}$ inches cut-off in the cylinders was the best. It gave that ratio of expansion of the steam with which was associated maximum economy in the circumstances, as found from many previous experiments.

With regard to the adoption of a different pressure for the two sets of trials, an inspection of the dates on which those trials were made would show that they were not intended to be put in juxtaposition. The earlier trials were the reheater trials. There he adopted a pressure of 200 lbs., because it was in accordance with American practice for the cylinder-ratio. Before making the vacuum trials a year or a year and a half later, many trials had been made, and it so happened they were being made at 150 lbs. pressure, and as it was as good as any other pressure it was adhered to. There was no significance in the particular pressure adopted, the great point being to ascertain the effect of two special conditions under

(Professor Weighton.)
which engines could work, reheating and not reheating in one case, and various vacua in the other case. With regard to finding that with a differently designed and constructed engine the best vacuum was higher, the trials had been made eliminating, as far as possible, that possible source of error. He was, however, always impressed with the doubt—and one or two of the speakers hinted at it—how far were results obtained from such an engine as the one at the College applicable, unaltered, *qualitatively*—there was no doubt about the quantitative matter—to other engines of different size? That raised a large question and one which no man could speak upon with any great certainty, without very much fuller information derived from experiments. As far as could be seen at present, there was no reason to suppose that the result obtained in the trials in a qualitative sense could be materially different from those which would be obtained from a larger or smaller engine, unless the difference in size was very great indeed. With regard to the quantitative result, that was a different matter altogether. In a larger engine a better result would be obtained on the whole, and with a smaller engine, worse, other things being equal. But that did not affect the comparison of the results obtained from any given size.

A point raised by Professor Watkinson (page 500) and another speaker, arose out of the question of the so-called smallness of the reheater, namely, the superheating of the receiver steam. Professor Watkinson thought that if the receiver steam had been superheated, the result would have been different. First of all he (Professor Weighton) did not think it was possible to superheat the whole of the steam passing through the receiver of an engine by steam taken from the boiler. He could not see how it was possible. It had been suggested that possibly a better arrangement of superheater might be made, but that did not affect the question which it was endeavoured to answer by the trials. It had been suggested to him that a better method of reheating would be to take the whole steam supply from the boiler through the reheater on its way to the high-pressure cylinder, but he did not think even that would superheat the steam in the receiver, and he questioned very much if it would be economical. The reasoning which underlay the supposition that

superheating of the receiver steam would lead to greater economy seemed to him to be akin to this, that if a little of something was bad, a great deal of it would be good. He did not quite see it himself; but he had long ago ceased to theorise about the steam-engine. A man who made experiments upon it soon saw the futility of theory, unless it was founded on many experiments. All he could say with regard to the proposals was that they might be right, but they were just as likely to be wrong. That also answered what Mr. Crosland (page 502) said about the reheater being too small. He had also answered what Mr. Saxon had said about the result obtained being typical only of the one engine. He granted there might be something in this, and that one was not justified in talking too definitely about it. He did not think there was very much in it qualitatively, but of course there was a great deal in it quantitatively. Mr. Saxon (page 503) also thought that the amount of steam used in an engine, and the load the engine was carrying, determined the vacuum desirable, and by inference he assumed that Mr. Saxon meant that if the engine had been tried on different loads, one would have found a different vacuum associated with maximum economy at each load.

Mr. Saxon said he referred to speeds and loads.

Professor Weighton said that introduced two variables at one time, the exact effects of each of which could not be arrived at. One condition only must be changed at a time. Professor Watkinson had raised the question of why the revolutions were not kept constant and the load varied, but he did not think there was much in that. To attempt to keep the revolutions absolutely constant, on an engine working on vacua such as were employed, meant adjusting the dynamometer, and it was impossible at various loads to keep the revolutions absolutely constant. For that reason he thought it better to keep the resistance constant in the dynamometer, and there would then be no reason for supposing that there was any changing of conditions about the engine which would affect the result. After all, the variations in the revolutions were small, and experiments had shown that such

(Professor Weighton.)

a degree of variation did not lead to any appreciable difference in economy. Again, Mr. Saxon did not seem to have noticed the Table with regard to the vacuum, and seemed to have a notion that the highest pressure was not used. The highest pressure was used, nearly 200 lbs., and an examination of Table 1 (pages 492–493) would show that the pressure in the high-pressure steam-chest was all along about constant at this figure.

Mr. SAXON said he did not refer to that at all. He was speaking of the other trials, not the trial with the reheater. He referred to the power developed according to Table 2 (pages 494–495), and had said that the higher vacuum developed the greatest power on the engine.

Professor WEIGHTON said that of course was in a general sense a truism. It followed that if the mean pressure was raised, *pari passu* the I.H.P. was raised. With regard to the advice which Mr. Saxon gave, that condensers should be built big enough to obtain the highest possible vacuum, he certainly agreed with that. What he maintained was, that whatever vacuum the condensers and pumps were built for, it would be found that working at the highest possible vacuum would not be working in the most economical fashion.

With regard to the question of lubrication that was a most important point. The cylinders were lubricated in the usual way with an impermeator on the H.P. steam chest, and the lubrication was kept constant in all trials in which the effect of lubrication was not an element to be determined. In all the trials the lubricator was kept going at a uniform rate. He had found incidentally that the amount of lubrication put into an engine affected the mechanical efficiency very much more than might be thought.

Communications.

Mr. C. HUMPHREY WINGFIELD wrote that such Papers as the one under discussion showed how much good work might be done in the numerous engineering laboratories scattered about the country, and he would like to suggest the desirability of some such systematic course of steam-engine research as was referred to in the Paper (page 483) being, by mutual arrangement between the various professors of engineering, carried out on similar lines and simultaneously on all the experimental engines available. Was it not possible for those professors to meet from time to time to discuss suggestions for subjects and methods of research, and to constitute themselves and their students members of a huge Research Committee? The results of some very interesting experiments with one particular engine were described in the Paper with admirable clearness, and would doubtless prove valuable, could one be sure that they are applicable to engines generally. This, in the absence of exactly similar experiments with other engines, such as he had suggested above, must remain a matter of individual opinion. On the other hand, if confirmed by such similar experiments the results obtained in researches of this kind might be of a value hard to overestimate.

The author referred (page 489) to the "sympathy" of the high-pressure and low-pressure exhausts. It was not sufficiently marked to swear to in the figures (page 490), but assuming its existence (and the author's statement that the steam entering the high-pressure cylinder varied in quantity with the vacuum in the low-pressure confirmed this), how did the author account for this cooling of the high-pressure cylinder? Was it solely due to conduction through the metal of the cylinders? This "sympathy" of the I.P. card was very marked, but this did not present any difficulty, as the exhaust is in direct communication during part of the stroke with the previously cooled low-pressure cylinder.

Would the author say what assumptions were made for the purpose of reducing his results to their equivalents at a constant

(Mr. C. Humphrey Wingfield.)

speed of revolution (page 487)? Although not strictly true, he presumed it had been assumed that the steam used per revolution was constant at all speeds. The writer was glad to see that the author (page 488) stated that his results as plotted in Fig. 3, Plate 60, were first reduced to the equivalent of heat-units, and he wished to know whether this was also done in Fig. 2.

It was pointed out (page 486) that there was a discrepancy between the results of Trials IX and X and the other pairs of trials as regards the effect of reheating on the water per I.H.P. Were the results of these two trials confirmed when repeated? He was prepared for a reduced mechanical efficiency, but was surprised to see that the water per I.H.P. was increased by the use of a reheater.

Professor WEIGHTON, in further reference to Mr. Saxon's remarks, noted several points which seemed to call for notice. First, there was nothing in the Paper advocating the building of any except the "most perfect condensing apparatus," but he demurred to the statement that an engine attendant had "ample opportunities of testing the best vacuum at which any particular engine under his charge would run" (page 503). Commercial engines were not usually fitted with apparatus for measuring the steam used and the brake horse-power developed, and without these at least, it would be quite impossible to find the best vacuum with any certainty. Second, the fitting of an automatic expansion governor to the high-pressure cut-off, in order to keep the engines at a constant speed, would not affect the results appreciably. Indeed such conditions of testing would have given much less instructive data than with a constant cut-off, because in the latter case the exact effect of the variable temperature on the condenser was more apparent. Third, Mr. Saxon said (page 503), "If an earlier cut-off had been used in the low-pressure cylinder, the steam would have been expanded down to a lower terminal pressure before being affected by the vacuum in the condenser." This statement was of course quite an error. The terminal pressure in the low-pressure cylinder was independent of the low-pressure cut-off point, and depended only upon the high-pressure cut-off and the cylinder ratio at given boiler pressure. Fourth, the Paper did

not refer to jet-condensing engines. The experiments were made with surface condensation, and the deductions referred to surface condensing engines only.

Thanks were due to Mr. C. Humphrey Wingfield (page 511), for the suggestion contained in his communication as to the desirability of collaboration in research work between the several laboratories of the country. He himself thought a good deal might be done in this direction, and trusted the future might bring it about. In answer to Mr. Wingfield's questions, he must confess that the "sympathy" of the high-pressure exhaust with that of the low-pressure was not visibly apparent in the indicator diagrams as published. This, however, was entirely due to the smallness of the scale of these diagrams, which scale was adopted to suit the page of the Institution Proceedings. In the original full-size diagrams, the point in question was very apparent and striking. It was not difficult to account for. A higher vacuum meant a greater temperature range in the low-pressure cylinder, and hence increased condensation during admission in that cylinder. This would lower the average pressure in the low-pressure receiver, and this in its turn would cause an enhanced temperature range in the intermediate cylinder, and therefore a greater condensation during admission to that cylinder. This again would lower the average pressure in the intermediate receiver, which in its turn would lead to an increased temperature range in the high-pressure cylinder, with its associated increased condensation during admission to that cylinder, and hence the increased weight of steam used by the engines per stroke, as shown by the measured quantities during the trials. Doubtless a portion of the cooling effect on the high-pressure cylinder was due to mere conduction, but the major part was undoubtedly due directly to augmented temperature ranges on the several cylinders, as traced above.

As regards reduction of the water used to constant revolutions, no assumptions were made, nor were any necessary. It would be seen that the operation simply consisted in multiplying the actual water used per revolution by a constant figure, and this could not affect the comparative results in the slightest. It was done solely

(Professor Weighton.)

for purposes of diagram representation. See Table 2 (pages 494–495), $W_1 = 120 \frac{W}{R}$.

The results of both series of trials were virtually expressed in heat-units, but for Fig. 2, Plate 60, it was not necessary to make any special reduction, except in the case of Trials I and II, Table 1 (page 492). Note 3 at the bottom of Table 1 gave the reason for this reduction. None of these trials were repeated. They were very carefully made, and previous experience had shown that repetition was of little or no use, unless the whole series was duplicated.

THE APPLICATION OF CYLINDRICAL STEAM DISTRIBUTING VALVES TO LOCOMOTIVES.

By Mr. WALTER M. SMITH, *Member*, of Gateshead.

Prior to the year 1887 piston valves had been tried experimentally in locomotive engines, but without much success, and the experiment invariably resulted in the piston valve being discarded. In 1887 the author turned his attention to the question, and endeavoured to produce a satisfactory piston valve, and in the following year a compound passenger engine was built fitted with piston valves of the type shown in Fig. 6, Plate 62. This engine had two cylinders, the high pressure being 18 inches in diameter, the low pressure 26 inches in diameter, the length of stroke in each case being 24 inches. One valve 7 inches in diameter was used for the H.P. and two valves 5½ inches for the L.P. cylinder, the latter valves being placed side by side and actuated by one rod connected to each of the valve spindles.

The main part of the valve consisted of a centre casting and two end caps mounted on the valve spindle, and retained in position between a collar and nut. The spaces between the caps and the centre casting were fitted with two rings, a wide one and a narrow one. Both rings, which had been turned slightly larger than the liner into which they were to work, were cut in one place. The narrow rings were placed on the exhaust side of the valve. Both rings were retained in positions relatively to each other, and with relation to a bridge in the liner covering the gap between the rings by a peg fixed in the centre casting and engaging the rings, the gap in the wide ring coming against a solid part of the narrow ring and *vice versâ*. The gap in the flange of the narrow ring was fitted with a tongue piece which prevented the escape of steam outwards. These rings, together with the body and ends of the valves, were made of cast-iron. This metal, after being at work for a short time, presents a good polished surface, and gives excellent results, the

wear being almost nil. The cylinders had fixed to them at either end a 2-inch spring loaded relief valve for the purpose of allowing trapped water to escape from the cylinders.

Goods Engine.—In 1891 a goods engine was built with cylinders and valves of the same size and form as those of the above-mentioned engine, with the exception that steam was admitted by the ends of the valves, instead of at the centre of the valve, as in the previous case. As an experiment, gun-metal rings were substituted for those of cast-iron. To get sufficient flexibility in the wide rings, the flanges formed on the same had to be made shallow. This gave very little end surface, and the rings after a time became loose; and it was found necessary to make these flanges deeper, and means had to be devised to prevent the rings being too rigid. The method adopted is shown in Fig. 7, Plate 62. Another and better method is shown in Fig. 8. To obtain a larger bearing surface the flanges are made deeper, with pear-shaped holes cast in the same, and from the bottom of these holes to the inner surface the metal is parted by saw cuts. This arrangement gives the necessary flexibility to the rings. To prevent the passage of steam where the ring is cut, a flat piece is fitted and riveted to the flange on the exhaust side of the ring. With this form of valve it was found in practice, chiefly with spare drivers, that the relief valves did not open quick enough to allow water trapped in the cylinders to escape in time to prevent damage to the cylinders. On the North Eastern Railway cylinder covers were broken, and on the Midland Railway cylinders were split, and more recently in America cylinders have been split and cylinder covers have been blown out. In each case relief valves were fitted to the cylinders.*

As shown in the following Table 1, a considerable saving in coal was effected by this engine, when compared with other engines of the same construction working in the same link. But the question is not altogether one of coal-saving; any device having this object in view must be submitted to argument, and not only proved by apparently sound reasoning, but by efficient practical application. The points it

* *Railway and Engineering Review*, 14 June 1902, page 446. *Railroad Gazette*, 14 July 1902, page 536.

is desired to emphasise are: the reduction of the amount of power absorbed in friction (1) in the valves and (2) in the valve motion; both are equally important, because the power gained in either case is utilized in producing extra work. The simplicity of the general arrangement of cylinders and valve motion also tends to reduce the cost of and the time occupied during repairs.

TABLE 1.

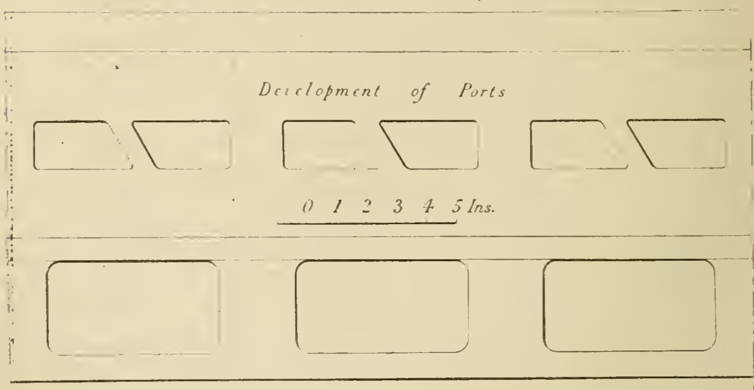
Mileage and Coal Consumption for Six Months ending December 1891.

Engine Number.		Total Miles run.	Coal in Lbs per Mile.
Slide Valves	1563	17,959	33·66
	513	19,018	33·92
	1315	15,903	34 25
	1564	19,874	34·34
	569	16,265	34·48
	1565	20,011	34·76
	424	18,492	35·48
	30	21,910	36·60
	51	18,960	36·65
	570	17,240	36·72
	1071	15,420	37·14
	Average	18,277	35·27
Piston Valves	107	20,329	32·05
A saving of 9·1 per cent.			

From the foregoing Table it will be seen that engine No. 107 burnt 1·6 lbs. of coal less per mile than the lowest in the link, and 3·22 lbs. per mile less than the average; equal to a saving of 9·1 per cent.

On the Midland Railway two engines were fitted with similar valves, and gave similar results. These facts, together with the existence of other possible advantages, made the subject generally of considerable interest and importance, and one which seemed worthy of further and careful study. The result of this study was the invention of an entirely new form of valve, illustrated in Fig. 9, Plate 63, and it was chiefly due to the assistance received at Derby, in carrying out experiments there, that this form of valve took a definite shape. As in the previous case a central casting with caps at each end is fixed on the valve spindle, between a collar and nut, and it is prevented from turning by

FIG. 10.—*Ports for 8-inch Valve, Fig. 9, Plate 63*



feathers let into the spindle. In this design the broad ring is turned, and then cut to form three equal segments. The lip shown on one flange is to hold the segments in position before the valve is placed in the liner, and to limit their wear to $\frac{1}{4}$ inch. Three segments and one flexible ring are fitted between each end cap and the body of the valve, and the segments are free to move outward to prevent the leakage of steam, and inward to allow trapped water to escape. Each segment is held central by a projection cast with it, which fits into a recess, formed in the end cap; sufficient space is left between the ends of the segments to allow them to collapse, so that trapped water is relieved from the cylinders. The segments, when forced inward by excessive pressure, bed on a

suitable surface formed on the end caps, and when the water is discharged the segments are forced outward against the liner by the pressure of steam in the steam-chest, and so become steam-tight. To prevent the passage of steam by the ends of the segments into the exhaust-chamber, the exhaust ring, made flexible by being cut, is placed between the segments and the exhaust-chamber. To prevent steam passing through the cut in the ring, a tongue piece is inserted across the opening. In the steam ports bridges are formed over which the ends of the segments, and the opening in the exhaust rings, travel; by this means steam is prevented from passing in or out of the cylinders by the ends of the segments and the opening in the exhaust rings. With this form of valve, trapped water escapes into the steam-chest, and also into the exhaust-chamber.

Passenger Engine.—In March 1894 an engine was built at Gateshead, and fitted with the valve last described. The following Table 2 shows a comparison between this engine and eight others of the same class, working in the same link, the difference being only in the form of the valves.

TABLE 2.

Mileage and Coal Consumption for Six Months ending December 1894.

Engine Number.		Total Miles run.	Coal in Lbs. per Mile.
Slide Valves	1621	18,521	32·33
	1620	24,113	32·76
	1624	28,253	33·45
	1623	20,104	33·88
	1627	22,367	34·18
	1626	14,675	34·74
	1622	17,129	35·20
	1631	23,032	36·08
Average		21,024	34·08
Segmental Valves	1639	28,890	29·55
A saving of 13·3 per cent.			

Three forms of Cylinders and Valves used on the North Eastern Railway.

FIG. 11.—*Inside Cylinder* 19″ × 26″. 1893.

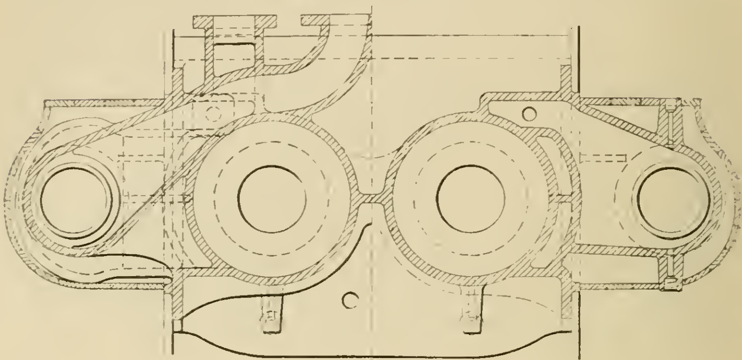


FIG. 13.—*Inside Cyl.* 19″ × 26″.

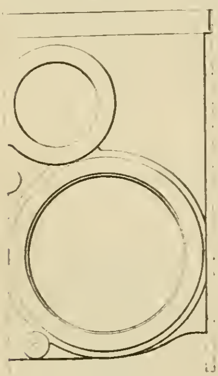
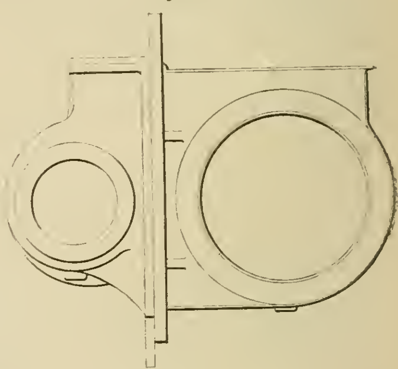


FIG. 14.—*Outside Cyl.* 20″ × 26″. 1901.



The coal used by engine No. 1639 was 2·78 lbs. less than by the one next to it, and 4·53 lbs. less than the average of the other engines doing the same work.

The wear of the segments for 29,000 miles was 0·01137 inch. This measurement is the average wear of four heads, and was obtained by taking the difference by weight of new and worn segments. Engine No. 1639 was one of a new type of main line

express passenger engines, coupled in four wheels with a leading bogie, diameter of the driving-wheels 7 feet 1 inch, the bogie wheels 3 feet 7 inches, cylinders 19 inches in diameter, length of stroke 26 inches; the cylinders were placed inside the frames, the steam-chests being outside, Fig. 11 (page 520). The original valves of this engine were replaced in November 1899 by the type shown in Fig. 12, Plate 63. This pattern of valve had been used in October 1894, in connection with the alterations made in rebuilding ten compound express engines.

The construction of the valve is similar to that shown in Fig. 9, Plate 63, the difference being in the exhaust ring. The cylinder arrangement is shown in Fig. 13 (page 520). After 1894, piston valves were introduced in other countries, and experiments with piston valves were being made on several railroads in America.* Such valves are now largely used in that country, and are applied in many of the recently constructed engines.

Engines altered.—In a former Paper † by the author, "Results of Recent Practical Experiments with Express Locomotive Engines," a comparison was made between different types of express engines, with relation to their fitness to perform a given duty; an engine rebuilt with piston valves is shown in Fig. 1, Plate 61. This engine was in every respect well in advance of the others. It did not show any signs of weakness.

Thirty-five passenger engines of different classes have now been altered; twenty-five of them have the valves arranged below the cylinders. The valves for these engines have given comparatively very little trouble.

Three-cylinder compound.—In 1898 engine No. 1619 was altered from a two-cylinder compound to one with three cylinders, Fig. 2, Plate 61. Fig. 15, Plate 64, and Fig. 16 (page 522) show the design of valve and liner used for the high-pressure cylinder.

The chief alteration in this design is that the segments are constructed so that the section is uniform in shape, and formed so

---

* *Railroad Gazette*, 30 August 1895, page 573.

† Proceedings 1898, page 605.

FIG. 16.
Ports in Valve, Fig. 15, Plate 61.

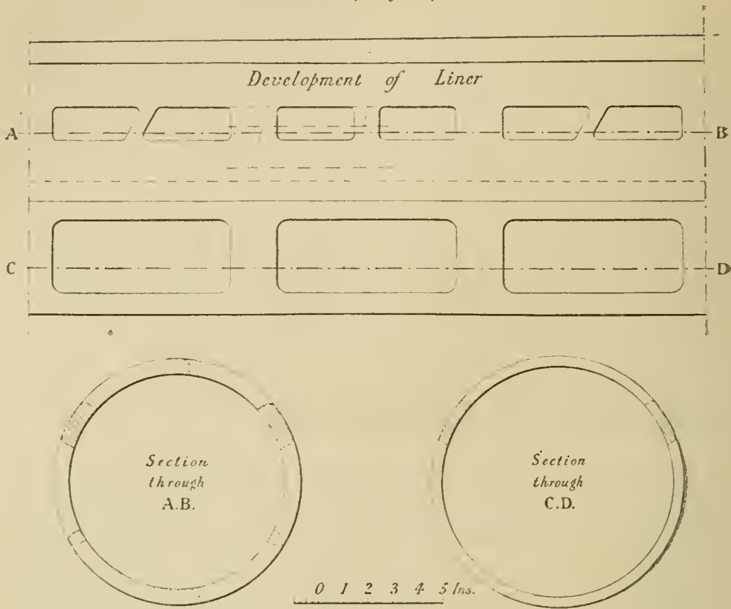
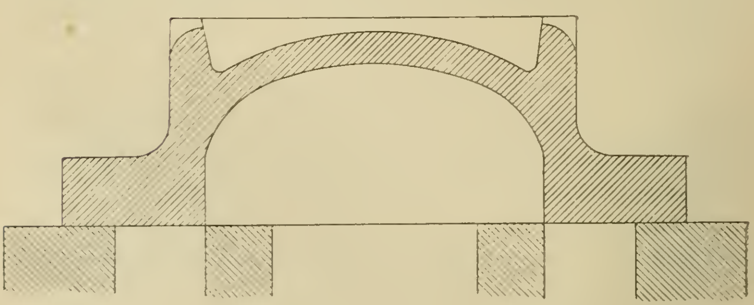


FIG. 17.
Cross-section of Valve for L.P. Cylinders.



that the ring from which they are made can be turned on the inside and so made to fit the end caps, thus reducing the cost of machine work. Fig. 17 (page 522) is a cross-section of the valve used for the low-pressure cylinders. On the 3rd of April 1902 one of these slide-valves broke while the engine was on its way to York with a heavy dining train. The engine having three cylinders was able to continue working its train. Slide-valves do occasionally break, and cause delay to traffic; however, should a segment of a circular valve break, the parts are held together, and the engine is not disabled. On the return of the engine to Gateshead, the valves were examined, and it was found that the flat valves had worn down from 1 inch to $\frac{1}{2}$ inch in thickness. These valves had to be replaced. The circular valve for the high-pressure cylinder was found to be in good condition, and was put back into its place; the average wear in all the segments was $\frac{1}{16}$ of an inch, the wear being in the ratio of 8 to 1. The valves were cast from the same alloy, and the mileage was 130,330, and at the present rate of wear the circular valves should show a very large increase in mileage.

Under normal conditions, the pressure on the back of the low-pressure cylinder valves would be 50 lbs. per square inch; that on the high-pressure valve would be a variable one, depending upon the distance the regulator was opened for the work to be done by the engine. The boiler-pressure for this engine is 200 lbs. per square inch.

New type of Express Engine.—In 1899 a new type of express passenger engine was designed and built at Gateshead, Fig. 3, Plate 61. The first engine, No. 2011, started to work in August, and ran 139,543 miles up to the 31st December 1901 without any appreciable wear in the valves or valve motion. The valves were taken out and sent to the works for examination, and were replaced by a duplicate set of valves, the segments, which were shown, and rings being made of cast-iron. On the first journey the engine went from Newcastle to Edinburgh 124$\frac{1}{2}$ miles at an average speed of 51 miles per hour without a stop, returning to Newcastle with the Scotchman the same morning; and afterwards went to Leeds and back on the same day, and has since continued to perform these journeys. The

average mileage for each month was 10,822. The engine was worked by a double shift of men. The total number of miles run by this engine from the time it left the shops up to the 30th of June 1902 was 204,475 miles.

To run heavy long-distance express trains with ordinary cast-iron slide-valves, direct from the planing or grinding machine, would involve considerable risk.

By the end of January 1900 ten engines of this class were at work; they have done equally well, the total mileage up to the 30th June 1902 being shown in Table 3.

TABLE 3.

Mileage of Engines Nos. 2011 *to* 2020 *inclusive, from commencement of running until* 30*th June* 1902.

	Engine No.	Total miles.
August 28th, 1899 . . .	2011	204,475
September 8th, 1899 . . .	2012	151,252
„ 6th, „ . . .	2013	161,061
October 20th, 1899 . . .	2014	121,989
November 16th, 1899 . . .	2015	130,732
„ 15th, „ . . .	2016	136,142
„ 30th, „ . . .	2017	145,423
December 14th, 1899 . . .	2018	141,524
January 23rd, 1900 . . .	2019	133,468
„ 12th, „ . . .	2020	127,244
	Total miles run by 2011 *Engine from January* 1*st to June* 30*th*, 1902.	
	2011	64,932

At the end of May 1902 twenty additional engines of this class were at work; these thirty engines have done better work, and cost less for repairs, than any other type of engine doing similar work. The cylinders are 19 inches in diameter with a stroke of 26 inches; the diameter of the driving wheels is 6 feet 10 inches, the diameter of the bogie wheels being 4 feet. The valves are $8\frac{3}{4}$ inches in diameter, and are placed below the cylinders. The valve is shown on Fig. 15, Plate 64, and Fig. 16 (page 522), and cylinders and motion arrangement, Figs. 18 to 24, Plates 65 to 68.

The total number of engines fitted with the combined form of circular and relief valve for the North Eastern Railway is eighty-six, and thirty are now being built.

Broken Valves.—In some cases segments and exhaust rings, Fig. 12, Plate 63, have broken, but there has not been a breakage in the form shown in Fig. 15, Plate 64. There is no difficulty in increasing the strength of the segments and exhaust rings so as to eliminate any risk of either breaking. Any breakage that has occurred can in most cases be traced to broken pieces of the main piston-ring coming in contact with the valve, while passing over the steam ports. There has been a difficulty with gun-metal, irrespective of the metal employed, in obtaining uniform results from what was expected to be the same mixture of metal.* Valves have lasted for years without showing any appreciable wear or defect, while others, supposed to be of the same metal, have worn away somewhat rapidly. What is required is a metal that will give consistent results at all times, without any special care being bestowed upon its manufacture. The object in employing different metals—a hard one for the liners and a softer one for the valves—was to get the liner to remain perfectly straight and cylindrical without any signs of barrelling, the greater wear to take place in the valves, they being more readily replaced. The valves are arranged to travel over the working face of the liners for a considerable distance.

* "Alloys of Copper and Tin," by W. Campbell. Proceedings 1901, page 1211.

Cast-Iron Valves.—The author has again resorted to the use of cast-iron, as it is possible to obtain a more uniform mixture and more uniform wear with cast-iron than with bronze. The surface of cast-iron becomes exceedingly hard, highly polished, and offers the minimum amount of friction and the chances of abrasion are few unless through negligence.

A piston-valve for a locomotive must be tight, and to be steam-tight the working surfaces must be in contact with each other. Surfaces in contact, with motion, means friction, and friction means wear in proportion to the amount of the friction and the nature of the metal employed. Under these conditions, it was not considered necessary, or even advisable, to make experiments with a solid piston head. Valves with solid heads may answer for other types of engines, but not in a general way for locomotives. Experiments were made with solid exhaust-rings; these did not run a couple of trips before the driver of the engine reported "valves blowing—to be examined." The valves were examined, and a number of small water grooves were turned in the ring; these, however, did not prevent leakage. The valves were again reported, and the rings had to be taken out and replaced by spring ones.

Relief of Trapped Water.—No piston-valve for a locomotive engine is complete unless it affords a free relief to water trapped in the cylinders, and such relief must be ample and instantaneous, so as to prevent fracture of one or more important and expensive parts.

The relief of water trapped in the cylinders with the segmental valve is, owing to the collapsible properties of the latter, practically instantaneous. When the piston is near the end of its stroke the segments cover the steam-ports, and are retained in position against the liner by the pressure of the steam in the steam-chest acting on their inner surface. Normally this pressure is only slightly greater than the pressure from the compression end of the cylinders acting on the outer surface of the segments, but when excessive pressure due to trapped water occurs the segments are collapsed, and an annular opening is formed, between the liner and the valve, through which the water escapes. With the ordinary slide-valve the pressure of water

in the cylinders may be excessive, the trapped water acting on the area of the steam-port against the pressure of steam in the steam-chest acting on the total area of the valve.

Excessive Compression.—The following experimental diagrams Fig. 25 (page 528) give some idea of the excessive pressure that may be obtained by too much compression. These diagrams were taken by the author from a compound engine in April 1887 to prove with this class of engine, as then constructed, that it was absolutely necessary to give a large inside clearance to the valves, so as to reduce the abnormal compression. It was found that the engines would not run at the speed for which they were built, nor would they haul the load intended; with a clearance of a quarter of an inch on either side inside the valve, the speed increased, because the compression was reduced. These diagrams are shown here to represent what has actually taken place between the piston and the end of the cylinder with the ordinary slide-valve; and what has to be provided for when using circular valves. The engine was running at a very moderate speed; in fact, it would have been impossible to have gone faster, for as it was, the hammering action was excessive.

Cylindrical valves, applied to locomotives, do not work under the same conditions as in other types of engines; for instance, it may be that in a locomotive the highest speed is obtained running down an incline with steam shut off.

The pumping action due to movement of the pistons is destroyed by the automatic admission of air and steam, but it sometimes happens that advantage is taken when descending inclines to fill the boiler with water up to the maximum limit. Should priming take place on the opening of the steam regulator, it must be instantly and automatically relieved.

The closing and opening of the steam regulator, owing to signal checks and various other causes, adds to the number of causes that tend to induce priming.

Air and Steam Valve.—The automatic air and steam valve was designed as an adjunct to the piston valve. After the regulator is

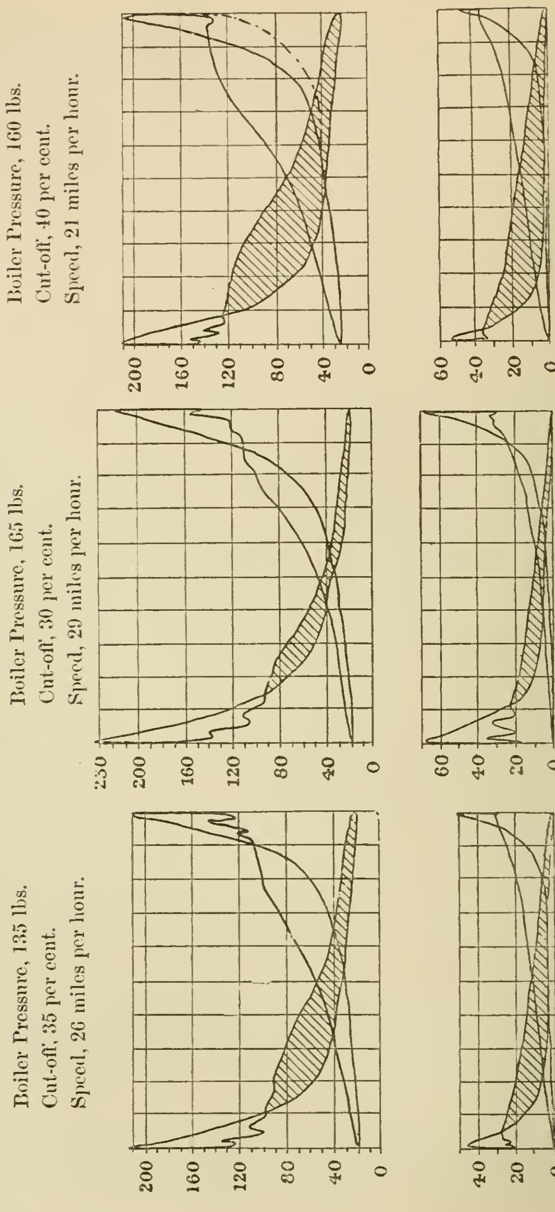


FIG. 25.—*H.P. and L.P. Diagrams, showing Excessive Compression.*

closed, the engine continues to run, and the action of the pistons in the cylinders creates a vacuum in the steam-chest. The object of the steam and air valve is to destroy this vacuum. The valve is shown in Fig. 26, Plate 69. When the contents of the steam-chest become rarefied, the atmospheric pressure causes the large valve to rise, and the small valve above this is lifted from its seat and steam from the boiler is allowed to enter the steam-chest. The steam thus automatically admitted lubricates the cylinders, pistons, and the distributing valves, and also acts as a cushion for the piston before it reaches the end of its stroke. The following diagram, Fig. 27, is taken from an engine running at sixty miles per hour:

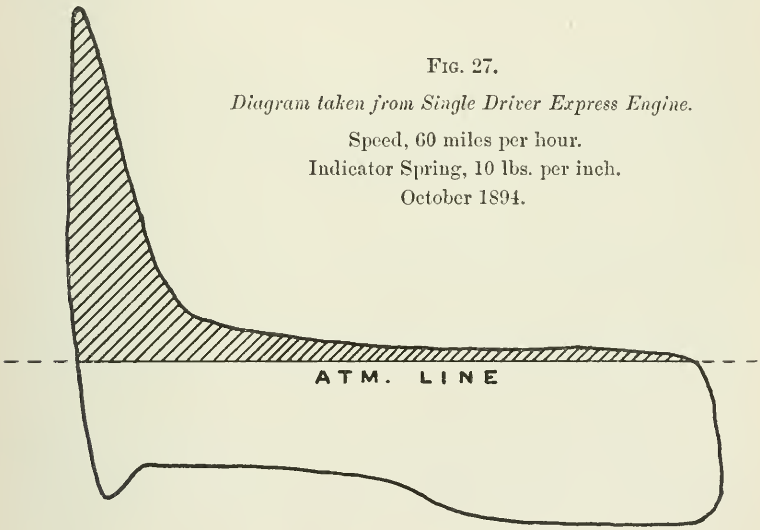


Fig. 27.

Diagram taken from Single Driver Express Engine.

Speed, 60 miles per hour.
Indicator Spring, 10 lbs. per inch.
October 1894.

Should the pressure in the steam-chest exceed that of the atmosphere, the valve automatically closes, and the connection between the boiler and the steam-chest is cut off. Under similar conditions, when the ordinary slide-valves are used alone, they are forced from the cylinder face by air drawn in through the exhaust-pipe. This is mixed with whatever is floating in the smoke-box; the cylinders

become dry from want of lubrication. When the valves are placed on the tops of the cylinders, they clatter as they are driven from the cylinder face with each stroke of the piston. A hammering action is thus set up, the strength of the blows increasing as the valves wear, since the lift of the valve becomes greater.

Inside Cylinders.—The cylinders are cast together with a steam-chest at either end. The steam-chests are connected by a passage formed in the casting, the exhaust-chamber being in the middle. The inclination of the cylinders and valve-chests is so arranged that the valve motion is direct. It is immaterial whether the valves are placed on the top of the cylinders or below them. If on the top the exhaust is more direct, and the cylinders can be made larger in diameter, as it is not necessary to have a passage between them for the escape of the exhaust steam. In either case very long steam-ports, with a direct and free exhaust, can be obtained. The liners in which the valves work are renewable, and can therefore be replaced at any time, thus in many cases prolonging the life of the cylinders. With the ordinary form of cylinder, it sometimes happens that the valve face is worn away before the cylinders are worn out, and in some instances it is not admissible to pin on a new face. Should the valve-liner barrel it can be bored out, or a simple machine with a travelling and revolving adjustable emery disc can be employed to true it up. A pair of cylinders is shown on the boring-mill, Fig. 28, Plate 69, but this machine is not arranged to bore the cylinders and the seats for the valve liners simultaneously; brackets are fixed on the cylinder boring-bars, arranged to carry an independent boring-bar for the liners; in this case the cylinder boring-bars have to remain stationary. The cylinders do not require, when once fixed, to be moved about and reset. The work done by the planing machine is reduced to a minimum; the arrangement described and shown on Fig. 28 suggests the designing of a boring-mill, so that the cylinders and seats for the valve-liners can be bored out at one and the same time. This would reduce the cost of the machine work.

Cost of Cylinders and Valves.—The cost of the new form of cylinders and valves has been compared with that of the ordinary cylinders and valves, and they do not differ much, but the figures are not of any permanent value. Machines adapted for the work to be done on the ordinary class of cylinders and valves are in existence, and the price has been cut down to the lowest figure, whilst, on the other hand, no special prices or machines have yet been made to reduce the cost to the lowest possible limit in the case of the segmental valves and their cylinders.

The first cost of the segmental valve, from the nature of its construction, should be a small one. The parts afterwards to be renewed are the segments and exhaust-rings. These are inexpensive; the other parts of the valve should last about the lifetime of the engine.

Comparative Pressure producing Friction: Slide-Valves and Segmental-Valves.—Fig. 29 (page 532) shows the variation of pressure producing friction on the slide-valve and the segmental-valves during their travel, cutting-off at 25 per cent. of the piston-stroke in the steam cylinder.

The indicator diagram is divided into twenty-six ordinates, each of which gives the pressure producing friction at that point. The force causing friction at each point was calculated from the areas acted on for the corresponding position of the valve, and from the pressure on the opposite sides for that position.

The diagram for the piston-valve is similar in construction to that for the slide-valve, and is shown in Fig. 29 (page 532).

Professor S. W. Robinson states, in his Paper*: "When the equilibrium area falls between that of the cavity and of the outside of the valve, it appears that the fluid pressing upon the top of the valve creeps under the edges to some extent, and the film of fluid under the valve near the cavity relieves itself by escape into the cavity. It would seem from this reasoning that for true surfaces a

* Transactions of the American Society of Mechanical Engineers, 1882–83, Vol. iv., page 151.

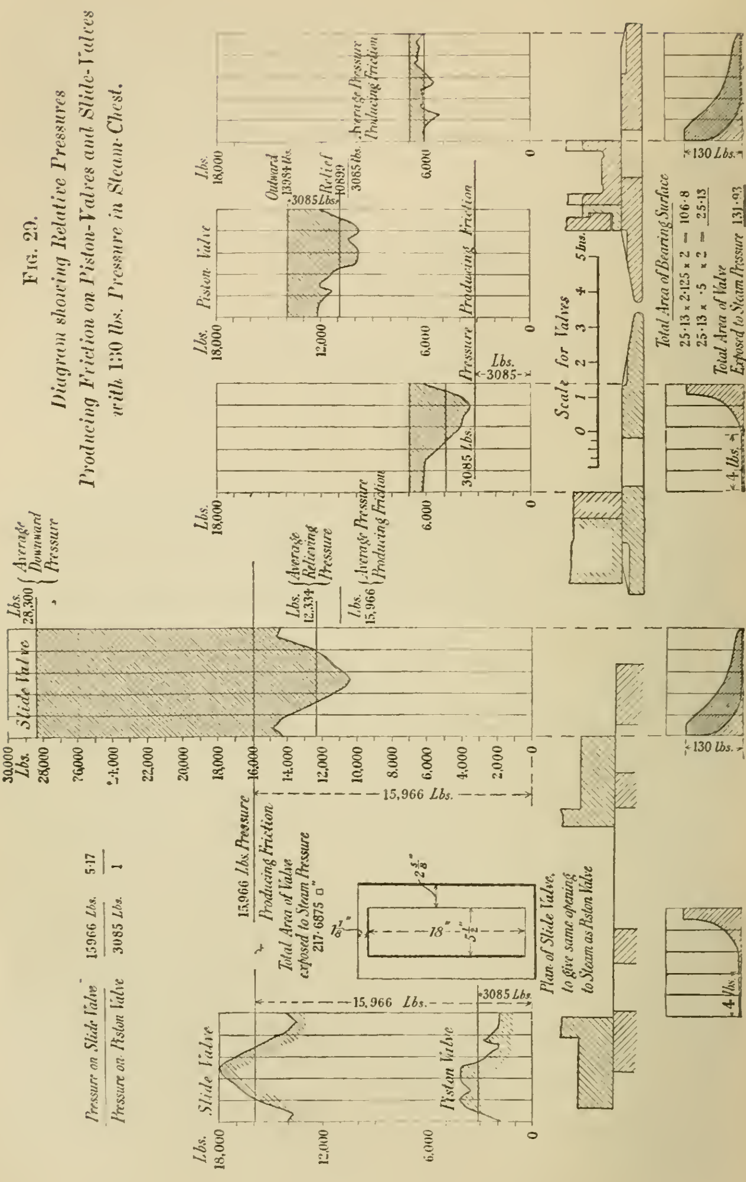


FIG. 29.

Diagram showing Relative Pressures Producing Friction on Piston-Valves and Slide-Valves with 130 lbs. Pressure in Steam-Chest.

film of almost infinitesimal thinness is constantly creeping along between the 'contact' surfaces towards the cavity; and that on this route, the pressure of the creeping fluid is continually falling, starting with nearly that of the higher pressure side of the valve, and ending at the cavity with the pressure of the latter.

"When the whole lifting pressure exerted by the creeping fluid between surfaces is known, the equilibrium line can be located. The theoretical determination of this lifting action is the same as that for finding the force tending to throw a packing ring from its seat."

It is stated in Unwin's "Machine Design" that $3\frac{1}{2}$ lbs. per square inch is sufficient to prevent steam passing between surfaces. In preparing the diagram a film of steam is assumed to be acting between the surfaces in contact of valve and seat. Had no film been assumed the pressure per square inch of surfaces in contact would be 320 lbs. for the slide-valve, and 137 lbs. for the segmental-valve, with steam at 130 lbs. in the steam-chest. Even at this low pressure—the pressure is reduced by wire-drawing by the regulator—the pressure per square inch would be too high for sliding surfaces. In the case of slide-blocks, well lubricated, the pressure per square inch should never exceed 120 lbs.

If it is assumed that a film of steam exists under all portions of the valve in contact at 126 lbs. per square inch, and that 4 lbs. is sufficient to prevent leakage under edges of valves from steam-chest to exhaust cavity, then in the case of the slide-valve with 130 lbs. average downward pressure on the back of valve the result is 28,300 lbs. with an average relieving pressure due to 126 lbs. film on surfaces in contact, to pressure in steam-ports acting on the under-side of lap of valve, and to 4 lbs. exhaust pressure acting on cavity of valve 12,334 lbs. The difference is 15,966 lbs. as the total downward pressure producing friction, and the maximum bearing area of face of valve is 78·2 square inches.

$$\frac{\text{Total pressure producing friction } 15{,}966}{\text{Area of surfaces in contact } 78 \cdot 2} = 204 \text{ lbs. per square inch.}$$

In contrast—dealing with the segmental-valve in a similar manner—the average total outward pressure on inside of valve is 13,984 lbs., and the average relieving pressure is 10,899 lbs. The difference between the two sums is 3,085 lbs. as the total pressure producing friction, and the maximum bearing area 75·4 lbs. per square inch; so that

$$\frac{\text{Total pressure producing friction } 3085}{\text{Area of surface in contact } 75\cdot 4} = 40\cdot 8 \text{ lbs. per square inch.}$$

$$\left.\begin{array}{l}\text{Pressure per square inch}\\ \text{producing friction .}\end{array}\right\} \frac{\text{Slide-valve . . } 204 \text{ lbs.}}{\text{Segmental-valve } 40\cdot 8 \text{ lbs.}} = 5\cdot 1 : 1$$

When the total pressure producing friction, and the coefficient of friction are known, the power absorbed by the valves and valve motion can be ascertained.

The following is a comparison from actual observation, which bears out that already given (page 523), so far as the comparison goes:—

Slide-valve: wear $\frac{21}{32}$ inch for 78,837 miles.

Segmental-valve: wear $\frac{1}{8}$ inch for 121,600 miles.

Wear of slide-valve per 100,000 miles $\frac{25}{32}$ inch.

Wear of segmental-valve per 100,000 miles $\frac{3}{32}$ inch.

In proportion of about 8 to 1.

As the friction on the valve is reduced, so is the wear and tear of the valve and valve motion, and so long as the valve motion remains true the engine will continue to give good results; not only in connection with the load it can draw, but also in connection with the coal it consumes.

On the distribution of steam to the cylinders much depends. The cost of repairs, and the time an engine requires to be laid idle during repairs, are items that require to be considered in designing an engine; for the longer the engine will run before it requires to be repaired, and the less the cost of and the time required for repairs, the more economical the engine will be. More mileage

will be run and more money earned in a given time. When segmental-valves are used, as a rule, the valve motion is simply taken down, cleaned, and put back into its place.

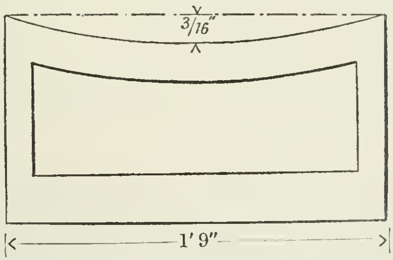
Such things as a break-down of valve gear or heating of eccentric straps are unknown.

Slide-Valves and Balanced Slide-Valves.—Mr. A. E. Seaton, in his book "Marine Engineering," page 247, states, "No system of relief frames, or plates has yet been tried which has given entire satisfaction; some indeed produce more resistance than they have been designed to reduce, and the best cannot be depended on for any very long period when exposed to the temperature of high-pressure steam." The author can from long experience corroborate the above statement. A good many years ago, on the Great Eastern Railway, most types of balanced valves were tried without success. Experiments were made about the same time, 1867–71, on the North London Railway, the results of these, with drawings, were communicated to the Institution of Civil Engineers by the late J. C. Park.*

Recently slide-valves have been observed which have actually seized on the valve face, and in some instances the edges of the valves have bent $\frac{3}{16}$ of an inch, Fig. 30. Great trouble was experienced in getting the valve motion to run any distance without heating. Balanced valves were put in, but to keep them steam-tight the

FIG. 30.

Distorted Slide-Valve, Edge bent $\frac{3}{16}$ inch.



* Proceedings, The Institution of Civil Engineers, vol. xcviii, 1888–9, part iv, page 396.

holes in the back of the valves had to be plugged up, thus destroying the attempt to balance the valve.

The author has to express his indebtedness to Mr. Wilson Worsdell, Chief Mechanical Engineer of the North Eastern Railway Company, for the opportunity afforded him in preparing and recording the information contained in this Paper.

The Paper is illustrated by Plates 61 to 69 and 10 Figs. in the letterpress.

Discussion.

The PRESIDENT said the members had to thank the author, not only for an account of some very interesting and successful results obtained with piston-valves, but also for tracing out the stages of design which had enabled him to attain those results. The author had paid attention to piston-valves for many years, and his experience was of extreme value. As far as he knew, the author's piston-valves were the only ones running in this country successfully on locomotives at present, and that he thought was an indication that the design of piston-valves was not a very simple matter. For that reason, if for no other, the members were very much indebted to Mr. Smith for explaining what the weak points of the earlier designs were, and how they had been overcome.

Sir EDWARD H. CARBUTT, Bart., Past-President, considered the Paper a most valuable one, and was glad to have had the experience of the North Eastern Railway on the subject of piston-valves. He was only sorry that Sir Lowthian Bell, the Chairman of the Locomotive Committee, who was cognisant of everything that went

on, had not added a word or two. It had been always a wonder to himself that piston-valves had not come more into earlier use. He had used piston-valves very largely in steam-hammers thirty years ago, and he believed every steam-hammer he made had a piston-valve. It had always been a mystery to him why locomotive engineers—and he had been brought up as a locomotive engineer—had not adopted the piston-valve. Mr. Martin, of Dowlais, was a great admirer of piston-valves, and came to Sir Edward to make him one for a blowing engine, which he believed was very successful. He could not understand why there was so much difficulty about piston-rings. Why were they not fitted as was done by Mr. Ramsbottom in his regular pistons, three light rings $\frac{3}{8}$ to $\frac{1}{4}$ inch in area? Mr. Ramsbottom used those rings in his pistons for years on dozens of locomotives, and therefore there must be something in it. It might be said that the difficulty of getting rid of the water was great, but Mr. Ramsbottom must have had the difficulty in his ordinary pistons. Those pistons were very nearly as big in diameter as were pistons when the locomotive first began, and therefore, instead of having loose parts with an expensive amount of fitting up, it would be much easier to put in three grooves and three Ramsbottom rings. Acting under Mr. Ramsbottom's advice his firm always put the three rings in the pistons for the steam-hammers, and found them very effective.

Mr. A. F. YARROW said he had had no experience in locomotive practice but adopted piston-valves for his torpedo-boat engines, which were all vertical engines; the case therefore was not quite on the same footing as in the case of locomotives. He much preferred piston-valves to slide-valves. It had to be admitted that a piston-valve was probably not so tight as a slide-valve, but one might pay too dearly for tightness. If the friction of the valve was considerable, which in a slide-valve it very often was, the tightness of the slide-valve might be secured by paying too dearly in the shape of friction and wear and tear. His firm had abandoned slide-valves for all cylinder, high-pressure, middle-pressure, and low-pressure, and had used piston-valves for years, and they appeared to

(Mr. A. F. Yarrow.)
work very well. He took it that the packing-ring in a piston-valve or in a piston had to do two things; one was to remain of the same diameter, as nearly as possible, as the cylinder, the other was to alter its form to allow for the distorting of the cylinder or valve case, due to the strains thrown on it from variations of temperature and the pressure of steam. In the piston-valves used by his firm the ring was solid, and he preferred it to any cut ring. With a cut ring the steam might get behind the ring, and the steam pressure behind the ring might be greater than that on the face of the ring, and the ring might be pressed against the cylinder walls producing friction, which in some cases was very excessive and threw a strain on all the valve gear. Now he had a floating ring, and the advantage of the floating ring over the solid valve was that the ring allowed for alterations in form, so that when the valve-chest got distorted through the strains, the ring followed its irregularity without difficulty. He was trying now some rings which were solid floating rings fitted into the solid pistons. The ring made was solid and very light and strong, and bolts and nuts were avoided, being objectionable, as in fast running engines they might get loose. Whether these rings would turn out well or not he did not know, but he saw no reason why they should not, because they were exactly similar to what he had used for years, except that he had done away with the junk ring.

The PRESIDENT asked how the rings were got on?

Mr. YARROW said there was no difficulty in getting the rings on; they were sprung over. It was quite easy to get half-a-crown through a hole the size of a shilling cut in a piece of paper, and just in the same way the ring could be got over the flange without any difficulty at all, although at first sight it might appear impossible. The piece of paper corresponded to the piston ring and the half-crown to the piston. He did not see why that method of construction should not turn out very well, because it was similar to what had been done for years, with the exception that the junk ring was avoided. The rings did not wear, there was

practically no friction. They were of fixed diameters, and the cylinders were of fixed diameters. If the rings were made 3-1000ths to 5-1000ths of an inch smaller than the cylinder, there would be practically no friction at all; there would be very little leakage, but he believed the amount of leakage in a suitable minimum difference of diameter was of less harm than the friction which would arise if the steam were allowed at the back of the ring, as in a cut ring.

Mr. Henry Carrick said he had not gone into the details of Mr. Smith's piston-valves, but had had many opportunities of seeing engines fitted with them at work, and found they started the trains easily and maintained the speed very well. He thought the author might well be complimented on the success he had made of piston-valves.

Sir Lowthian Bell, Bart., Past-President, said that with regard to what had fallen from his friend, Sir Edward Carbutt, it was no part of his duty as the Chairman of the Locomotive Committee to assist in improving the locomotive. He confined his inquiries to ascertaining whether improvements introduced by professional and practical engineers were followed by the economy stated in the proposals. He hoped the meeting did not for one moment suppose he meant any discourtesy in not responding favourably to the appeal made to him by the President to speak.

Mr. Charles Baister said that, as a North Eastern Railway man, he had had very considerable experience of running locomotives, and thought that slide-valves were one of the most fruitful sources of engine failure. Frequently the flat valves were broken in various ways, especially those on the top of the cylinder. He did not remember one single case of an engine failure resulting from a piston-valve since they were first adopted. He had to deal with the engine failures which occurred in running East Coast trains. They ran some very good expresses on the North Eastern Railway, and he was more or less responsible for every engine failure that occurred whilst working those trains; he was therefore very grateful to Mr. Smith for his piston-valve.

Professor W. J. LINEHAM, as an old locomotive man, felt a keen interest in locomotives. He quite expected that the introduction of the piston-valve would be an advantage, because the slide-valves were gradually getting larger and larger. He drew attention to the mention in the Paper of an engine being disabled, it being stated that on the return of the engine to Gateshead the valves were examined, and it was found that the flat valves had worn down from 1 inch to $\frac{1}{2}$ inch in thickness. That, he thought, was not an unusual experience with slide-valves. There was not alone the wear, but the wear into all sorts of strange shapes, which caused a great deal of trouble. Therefore the piston-valve was bound to turn out better. Locomotive engineers looked on those things from the point of view of convenience rather than economy. Not a word about economy had been mentioned that morning with regard to the valves; nor was it mentioned, he believed, in the Paper, except with regard to the friction of the slide-valve.

He did not think the Paper should be allowed to pass without noticing the disadvantages of the piston-valve. Anyone who had tried to design piston-valves would find that there was an immense amount of clearance necessary to get a free passage, and that was found also in marine practice. Piston-valves were used because they were better than slide-valves, without regard to economy. He believed that in the case of marine engines 25 per cent. of the cylinder working volume was not an unusual amount for clearance. That was very high, and must affect the economy of the engine considerably. He drew attention to the possible use of mushroom-valves. Two years ago at the Summer Meeting in London he mentioned the matter,* and he was still a great believer in the advent of the mushroom-valve. There was an old maxim that if a thing was right, it was sure to come in the end, and he believed mushroom-valves would come in the end. In gas-engines and oil-engines they had shown themselves to be very useful. They were easily made tight when worn, and they were very efficient and would work at very high velocities. In addition, as water must be

* Proceedings 1900, page 421.

allowed to re-pass the valve if it formed in the cylinder, that could be done in the case of the mushroom-valves even better than with the piston-valves. He believed the piston-valve was an immense advance on the slide-valve, but he believed the mushroom-valve would be an immense advance on the piston-valve.

Mr. J. D. TWINBERROW said he had the pleasure and privilege of working under Mr. Smith when he first took up the design of piston-valves, and he considered it was appropriate that the development of that description of valve for locomotives should take place on the North Eastern Railway, because the Stockton and Darlington section of that railway before the amalgamation was one of the first to make the experiment of applying piston-valves to locomotives. Some remarkable engines were built many years ago which had piston-valves, outside cylinders with a stroke of 30 inches, and four-coupled wheels. The valves were plain discs of bronze 12 inches in diameter, but it was not very long before they were taken out altogether. Mr. Smith had attacked the peculiar difficulties surrounding the working of these valves in locomotives, and which differentiated the problem from that which occurred in marine or other practice. Piston-valves which gave satisfactory results in marine and stationary engines might be perfectly useless, if put to work under locomotive conditions. One of the chief points of difference was in the collapsible qualities of the valve; the necessity for such a provision had been proved from time to time, and was one of the features by which Mr. Smith had achieved success. Some designers of piston-valves attempted to eliminate friction by making the valve-rings to float in the liner without actual contact, but he did not think that, for working heavy trains at the rate of 150,000 miles per annum, a floating valve would be found capable of maintaining satisfactory tightness under the peculiar conditions of locomotive work, whereas the sectional rings of the cylindrical valves did so, although it was admitted they had a slightly greater friction than floating valves. That friction, however, was not sufficient to cause wear. He had a little experience some time ago with a large horizontal engine fitted with floating piston-valves. It was said

(Mr. J. D. Twinberrow.)
there would be no friction, but when set to work, it was not long before most of the valve-gear was carried away. An attempt was made to remove the valve by hand; it required a large number of hands and five-ton blocks and tackles before the valve would budge.

A reference was made in the Paper to clearance of high-pressure cylinders of compound locomotives. Many designers were apt to overlook the necessary provision of clearance volume in their endeavour to reduce the clearance surface. A reasonable amount of clearance volume was a necessity for high-speed locomotives, particularly in high-pressure cylinders of compound engines. It was the custom in France to fit flat cylinder-ends, although the pistons were of single-plate pattern deeply dished on both faces. In that way they maintained a satisfactory clearance volume, whilst the clearance surface was less than that incidental to the use of dished covers. In many classes of compound engines introduced in this country a sufficient clearance had not been allowed; the compression had consequently been too high, and had been reduced by resetting the valve-gear and giving excessive clearance on the exhaust edges of the valves. The duty imposed upon mushroom valves, when used to distribute steam, was distinctly different from that when used in oil-engines. It was a characteristic of the internal-combustion engine that the valve was not raised against the full working pressure. Some time ago he spent a good deal of time scheming the adaptation of double-beat valves to locomotives, but he had arrived at the conclusion that the salvation of the locomotive valve-gear was not to be found in that direction. Anyone might see for himself the fine work which was done by the class of engines recently turned out from Gateshead, and how largely they had diminished the extravagant practice of double-heading the trains. The East Coast expresses, which frequently had upwards of fifty axles behind the tender, were worked with these engines unassisted, and he did not think there was any other company doing better work at the present time than the North Eastern Railway with Mr. Smith's piston-valves.

Communications.

Mr. Henry Lea, Member of Council, wrote that it was easy enough to design and to make a piston valve, but it was quite another thing to find that valve steam-tight after a long period. Piston-valves that belonged to steam-engines which exhausted into condensers or into long pipes leading to chimney stacks or elsewhere might leak badly for a long time before such leakage was detected, but locomotive engineers occupied an exceptionally good position in regard to the behaviour of the valves of their engines, for the exhaust nozzle was within say 15 feet of the ear of the engine driver, who by long practice instantly detected leakage, and could determine whether it proceeded from the pistons or valves. In the event of such leakage taking place, he reported the same on the day on which it occurred, and such reports received due attention. It appeared to him, therefore, that any piston-valve such as Mr. Smith's, which would pass through the ordeal above mentioned, and remain steam-tight after a long period of working, deserved far more consideration than piston-valves which were put to work under less exacting conditions. He himself had known a bonnet taken off the valve-chamber of a 200-H.P. engine, and when the steam was turned on, a column of steam rushed past the valve packings and reached the roof of a lofty engine room. Prior to this test the valve was supposed to be in good condition.

Mr. Smith wrote, in reply to the discussion, that locomotive engineers had introduced piston-valves of the same type as those used in land and in marine engines (page 537). These valves having been found unsuitable were discarded. With reference to Sir Edward Carbutt's remarks (page 537), the difficulty with piston-rings, solid or cut, floating or otherwise, was to keep them steam-tight for any length of time. It was true that Mr. Ramsbottom and others had used piston-rings in their ordinary pistons without much difficulty, but the piston-valve for distributing steam to the cylinders differed from the ordinary piston. If two pistons of similar

(Mr. Smith.)
construction were used together, one for the main cylinder and the other for distributing steam to the cylinder, water trapped between the two could not escape; it would be confined between solid heads. After the clearance space between the heads was filled with water, any further movement of the main piston in the cylinder would split the same, or force the end out; the trapped water would then escape. Under similar circumstances, when water was confined between the piston and the ordinary slide-valve, the valve was forced from the cylinder face, leaving a space through which the water escaped from the cylinder.

The author agreed with Mr. Yarrow (page 537), that a piston-valve for a marine engine might not be so tight as an ordinary valve; but in the case of a locomotive, steam-tightness was an absolute necessity. The segmental valve was designed so that the surfaces were always in contact with each other. The inward and outward pressure on the segments was to a great extent balanced, the outward pressure being sufficient to keep the segments tight against the liner in which they worked. The rings and segments were merely turned and placed, fitting easily, in the heads. The flanges on the segments were so proportioned that the steam in the steam-chest forced the segments against the exhaust-ring, and the exhaust-ring against the centre casting, and so leakage of steam between the joints was prevented.

In reply to Mr. Lineham (page 540), the author did not consider it necessary to do more than give two Tables (pages 517 and 519) showing the difference in the consumption of coal. With regard to clearance, no difficulty was experienced in designing cylinders to give a free passage for the inlet and outlet of steam, with a clearance of from 5·5 to 8 per cent. of the cylinder working volume. The author has obtained the best results with a clearance of about 7 per cent. As a matter of fact, the clearance with cylindrical valves could be made less than with ordinary valves.

MECHANICAL APPLIANCES IN MINES.

(Coal Cutting and Drilling.)

By Mr. R. H. WAINFORD, *Member*, of Newcastle-upon-Tyne.

By reason of its bearing upon other great industries, besides being in itself the most important industry of this country, there is no question which should demand more serious consideration than the cost of obtaining coal. While we have our coal, it is said, we shall continue to hold a strong position in the commercial world as well as in other respects, that is, while we have cheap coal; great fear is frequently expressed as to the future of England as a producer, competition from abroad is met with in every direction, and even the coal trade is being menaced, and economies should be looked to.

It is true that up to the present time the iron and steel industries have suffered more from outside competition than the coal trade is probably ever likely to do; but it is equally true these trades would not have been so seriously affected, had the fuel they required been produced on the most economical lines, and therefore put on to the market at lower prices than prevails. If fuel can be procured at low rates, in a much greater measure will the cost of making finished iron and steel, and even engines and ships, be affected, for it must be remembered that it takes $2\frac{1}{2}$ to 3 tons of coal to produce a ton of

finished iron or steel, and from $3\frac{1}{2}$ to 9 tons for every ton of engineers' work completed. A saving therefore in the initial stage of operations, in the cost of coal, is a boon, not only to the mine but to those who are, as indicated, dependent upon its produce; if the steel maker could buy fuel at say one shilling a ton less cost, he would accordingly produce a finished bar or plate at 2*s.* 6*d.* to 3*s.* less cost per ton. Such a difference should place him in a fair way to meet outside competition; in the author's opinion even the country works—which under present conditions cannot exist—would even have a chance, were it possible to establish an all-round reduction in the cost of coal anything like approaching the amount mentioned.

The application of mechanical drills and coal-cutters presents the means by which the greatest economics can be shown; there are other means of economising. Mr. James S. Dixon, of Glasgow, suggested them in his opening address to the Institution of Mining Engineers a few weeks ago,* but the object of this Paper is to draw particular attention to work which may be and is done at the coal face by drills and coal-cutters.

From reports it is gathered that mechanical drills and coal-cutters are pretty generally used in America—it is said the Ingersoll Company have about 3,000 coal-cutters operating; in Belgium, France and Germany power drills are used a good deal, but coal-cutters are not so much applied as in England and Scotland. The author recently visited several collieries on the Continent, and there witnessed some five or six different types of coal-getters operating. These are described, but it may be incidentally remarked, it is not his wish to specialise them, as there are many machines in the

---

* Mr. Dixon remarked that coal working by machinery was making considerable progress; by the application of electricity and high-pressure steam improved engines, at least one-half of the present consumption of fuel in mines could be reduced, and 8,000,000 to 10,000,000 tons of fuel saved to the country.

The author suggests that further reduction in consumption of fuel may in the near future be maintained by the introduction of gas-motors; recent developments prove that a gas-engine can be run economically with common producer gas; producers may therefore take the place of boilers for all auxiliary purposes.

market equally as good; they are given because operations have been witnessed, and the results are from actual practice. A suggestion has been made that it would be a great boon to others as well as to the mines, if a reduction of one shilling per ton in the cost of producing coal could be shown. The following figures may prove the possibility, in which case an important problem would be faced, a thing worth while pondering over. On the output of Great Britain, it would show a saving of over £10,000,000 per annum. Some of the collieries could not show a gain by using drills and cutters, others might be able to adopt one or the other, but it is extremely likely that at least 60 per cent. of the mines could adopt both to advantage, to amounts ranging from 6*d.* to 4*s.* 6*d.* per ton of coal produced. Sixty per cent. on £10,000,000 is a big item.

It may here be mentioned that the advantages gained by mechanical means do not end in the simple reduction in cost of getting—there is also a substantial gain in having a coal of enhanced value due to there being a greater percentage of round coal (not so much slack made); there would be a less number of men actually working at the coal face, the most dangerous point in a mine, and consequently a reduction in the number of claims for compensation. There is another important factor, namely, that of houses for workmen; in fact, this latter, taken in a broad sense, is capable of repaying capital outlay for plant. From this it is not to be assumed, that all the men taken from the face are to be thrown out of work, but rather, the output of each pit is so much increased that work of a less dangerous nature will be available for them in the pit; an outlet will also be found in the iron and steel works, which it is to be assumed would have increased business, to the detriment of the imports of iron and steel, and in fact of general engineering work. Thus it will be gathered that the introduction of mechanical appliances at the coal face does not necessarily mean paying off men, but it does suggest largely increased output, both in the mines and kindred trades. It may be urged still further—it is due to the ironworks and engineers—that improved conditions in coal winning should be vigorously pushed forward. The idea of curtailing the output of coal, in order that high prices may be maintained, is diametrically opposed to the foregoing suggestion—

which idea represents one of the many disadvantages of piece-work; and when considering mechanical methods, it should be prosecuted with the ultimate intention of paying wages by the day or hour, and not on tonnage.

Advantages of curving or holing by mechanical methods over hand-labour.—Generally the machines do this work under the coal, whereas the miner holes in the coal, and from a commercial point of view a distinct gain in favour of machine practice is established, there being a reduction in the amount of slack made. Something like 90 per cent. of the coal got by machines will pass over a $\frac{7}{8}$-inch screen mesh, as against 60 per cent. by the hand method. For the purpose of ascertaining the difference in selling values, an exhaustive trial was made at a Lancashire colliery with these results:—

		£	s.	d.
*Hand-labour:—	3 tons coal at 11*s*. per ton	1	13	0
	1 ton slack at 7*s*. 3*d*. per ton	0	7	3
	Value per ton, average	0	10	$0\frac{3}{4}$
By machine:—	8 tons coal at 11*s*. per ton	4	8	0
	1 ton slack at 7*s*. 3*d*. per ton	0	7	3
	Value per ton, average	0	10	7

An increase of $6\frac{1}{4}d$. per ton in value.

The foregoing figures are the result of work performed some time ago by a Winstanley disc coal-cutter; similar results are maintained at the present time, namely where a miner produces 3 tons of coal to one of slack, a machine will get 8 tons of coal to one of slack. This advantage is somewhat discounted by the fact of slack being nearly as valuable as coal for coking purposes; a better quality of coke is, however, made from disintegrated coal than from slack, as it is free from dirt—an element not entirely overcome by washing. If the coal is house or steam coal, then the advantage is fully maintained.

Therefore if $6\frac{1}{4}d$. can be realised in this manner, the amount may reasonably be placed to the credit of mechanical appliances,

* These figures are taken from the recently published book by Sydney F. Walker, page 48, "Coal Cutting by Machinery in the United Kingdom."

and then more than half of the shilling suggested as the possible saving is established. It is not proposed to set anything down definitely as to compensation claims, although experience has shown that accidents occur very much less frequently where machines are in use. Mr. Garforth of Normanton instances this in a concise manner. He says "four accidents occurred in getting 1,100,000 tons of coal by machines, as against a similar number of accidents in getting 315,000 tons by the old pick method. If Mr. Garforth's experience could be taken as representing average conditions, then somewhere about 0·375 penny per ton is saved in this direction, which is however a minor consideration compared with the increased safety of the pit. But the third item, houses for workmen, should prove important; whether the gain is established by maintaining a constant output with fewer men, or the output is increased with the same number of men employed, preferably the latter, the costs will have diminished, say, by a penny per ton. There is now left, if that amount is allowed, $4\frac{3}{4}d.$ to be made by the mechanical appliances themselves, coal-cutters and drills at the coal face. For the purpose of making direct comparison as to the work of machines *v.* hand-labour, it is advisable to fix upon normal conditions, and to do this a 3-foot seam may be reasonably and fairly regarded as the average. Coal can be holed by machines in this thickness to advantage; as they get thicker the saving is decreased, and as they become thinner they increase; the machine may cease to show a gain when the thickness exceeds 5 feet, on the other hand the best results have been attained in seams under 2 feet thick. A good miner will hole, curve, get, and fill three tons a day of 8 hours in a 3-foot seam under normal conditions, and in so doing will have earned, say, 7*s.* 6*d.*; the cost for "holing or curving," getting and filling is therefore 2*s.* 6*d.* per ton. There is little doubt as to this figure, namely, 2*s.* 6*d.* per ton, being below the average on the total output of Great Britain, so the rate may be accepted.

The capital outlay for a complete coal-cutting plant is here considered, with allowances made for interest on capital, depreciation, repairs, cost of running, stores, &c., and a figure arrived at to stand against the machine.

The estimated cost of a single coal-cutting machine plant:—For one machine complete with all fixings and power plant, exclusive of boiler, engine house and foundations, £1,000; the standing charges are as follows:—

	£	s.	d.
For interest and depreciation at 15 per cent. per annum of 300 working shifts	150	0	0
For repairs and stores	75	0	0
For power (fuel)	60	0	0
	285	0	0

£285 ÷ 300 shifts = 19*s.* per shift.

The specification of a single machine installation complete, as estimated above, includes engine and dynamo, electric standard type coal-cutter and all accessories and connections from the generator to the machine at a face half a mile from the shaft, erecting the plant and running it for ten days. No account is taken for attendance at the generating station. It may be here suggested, that when the cutters are worked on the night turn, which is usual, the fuel account would hardly be appreciable, as the steam in this case will be drawn from boilers that are not in use, although in steam.

For an electric installation, the compressed-air plant may be taken over all to be about equal in cost. Some slight differences occur in the prices for the Hurd, Clarke-Stephenson, and Diamond; the sum £1,000 is not exceeded, however, in any case.

The coal-cutter will hole or curve to a depth varying from 3½ feet to 6 feet; the average working depth is 4½ feet, and in 8 hours it will travel across a face 70 yards under normal conditions, holing or curving through a distance on the face, which when got and filled equals 100 tons; the same falling off and increase in the make applies here, so the average may be taken as stated. Sometimes two men only are required to look after the machine, and never more than three; if these men are paid at the same rate as the miner, the holing through 70 yards will then cost 7*s.* 6*d.* × 3 = 22*s.* 6*d.*, less if anything, because two men may be enough to do the work.

For getting down and filling (11*d.* per ton standard* + 57½ per cent.) cost per ton = 1*s.* 6·46*d.*, and the total for holing or curving, getting and filling, 100 tons is :—

	£	s.	d.		s.	d.	
For special machine men (holing) . .	1	2	6	or	0	2·7	per ton
„ getting and filling	7	13	10	„	1	6·46	„ „
„ holing, getting, and filling . . .	8	16	4	„	1	9·16	„ „

Bringing forward the amount estimated as the standing charge per shift against a single machine plant, the following results are obtained :—

	£	s.	d.		s.	d.	
For holing, getting and filling 100 tons .	8	16	4	or	1	9·16	per ton
„ standing charges, interest, &c., 100 tons	0	19	0	„	0	2·28	„ „
	9	15	4		1	11·44	„ „

The reduction therefore is 6·56 pence on the 2*s.* 6*d.* rate in favour of the machine, and, together with the amount previously estimated as savings due to increased selling value, &c., of 7·25 pence = 13·81 pence. The unfavourable points in the foregoing estimates are found in the fact that, whereas a single-machine plant is put down at £1000, a two-machine plant costs £1,575, a three-machine plant £2,125, and a four-machine plant £2,950 approximately.

The following results obtained by the Hurd bar-type machine, Plate 72, and the two disc-machines of the Diamond Coal-Cutter Co., Plates 74 and 75, and the Clarke-Stephenson, Plate 73, will to a great extent verify the above figures :—The Hurd machine, Plate 72. at a colliery in North Staffordshire has holed over a period of twelve months an average of 100 yards, 4 feet deep in hard fireclay below the coal—the machine making its own pavement; the cost by hand was 2*s.* 1*d.* and the machine showed a saving of over 6½*d.* per ton, after allowing for all charges; the gross difference at the face being 10*d.* per ton. At a colliery in Yorkshire

* This low figure is taken from a colliery in South Yorkshire worked by the Diamond Cutters, and is attributable to the deep undercut, which gives the men a good buttock to work at. (See detailed labour bill in Appendix II, page 564.)

a medium sized machine holed 3,600 yards, 4 feet under in a 7 weeks' trial, working single shifts daily—the Saturday being a 6 hours' shift; the saving effected was 1*s.* on a 3*s.* 6*d.* rate—the holing in this instance being in a hard black band. Another case to be mentioned effected a clear saving of 1*s.* 3*d.* per ton; this is in the Midlands district, and it is interesting to note that the first machine was put in over a year ago and no repairs have been required, though the holing is very hard and the temperature in the pit is 80° F. The Diamond coal-cutters, Plates 74 and 75, at a colliery in South Yorkshire, hole from 700 to 800 tons per day in a 4-foot seam. The holing is made in the bottom dirt and inferior coal which contains a large quantity of pyrites. The output by hand was $3\frac{1}{4}$ tons per man, which has been increased, by means of the deep under-cut introduced by the makers of this machine, to 6 tons by the machines; the price was 2*s.* $1\frac{1}{2}d.$ per ton by hand and is reduced to 1*s.* $3\frac{1}{2}d.$ by the coal-cutters, a difference of 10*d.* per ton at the face, from which must be deducted interest on capital, &c.; an average of 80 yards per machine per shift of 8 hours is maintained, the depth of holing being $5\frac{1}{2}$ feet; to a mining engineer 80 yards, $5\frac{1}{2}$ feet under, not only represents a large superficial area of coal, but implies better coal, less shots, road-making, timbering and an all-round reduction in getting price. At another colliery where the seam lies at an angle of 25° the holing is made to the rise; the getting price was formerly 2*s.* 3*d.* per ton by hand as compared with 1*s.* $4\frac{1}{2}d.$ per ton by machines. At a colliery in Durham a saving of 2*s.* per ton in a 2-foot seam is made, and at another place in Yorkshire, in a seam 19 inches thick, a saving of nearly 4*s.* per ton has been established, thus showing as previously stated, that as the seams get thinner the saving increases. The Clarke-Stephenson (Messrs. Ernest Scott and Mountain) is installed in a large number of collieries in Yorkshire and district, similar in design to the drawing, Plate 73, and in every case without exception savings have been effected, bearing out the author's remarks as to the all-round reduction in the cost of producing coals. It may suffice to quote one instance: this is in a 3-foot seam in the Barnsley district; the contract price for cutting is $3\frac{1}{4}d.$ per yard producing 15 cwts. of coal, and the filling price is 1*s.* 3*d.* = 1*s.* $6\frac{1}{4}d.$ all told.

The price of hand-labour in this seam was 3*s.* per ton. The total amount of yardage cut by the coal-cutting machine is about 4,000 per week, the total output of the pit being 3,000 tons; the depth of undercut is 3 feet 6 inches, and apart from the saving in connection with the coal-cutting plant is the fact that the coal produced is worth at least 1*s.* 6*d.* per ton more on the average, due to the great reduction in amount of small made. Formerly this seam could not be worked by hand except at a loss.

The cutters instanced are of course longwall machines; for pillar and stall and general holing work a machine made by Frölich and Klupfel, Unter-Barmen, is doing excellent work in Germany. Drawings, Plates 70 and 71, show the system, and the undermentioned figures give an idea of holing operations :—

Trial with the Frölich Machine at the Reden Pit, Saarbrücken.

Date.	Seam.	Time Cutting.	Depth of Cut.	Width of Cut.	Area.	Remarks.
1901		mins.	mètre.	mètre.	m^2.	
12 June	Landsweiler Hauptbasck	90	—	—	3,06	2 drills broken.
13 "	11 Tiefban Heiligenwalden	55	1,60	2,00	3,20	20 minutes stoppage for adjustments.
14 "	"	54	1,80	1,65	2,98	
15 "	Kallenberg	75	2,25	2,15	4,80	

Trial with the Frölich Machine at the Heinitz Pit, Saarbrücken.

Date.	Seam.	Time Cutting.	Depth of Cut.	Width of Cut.	Area.	Remarks.
1901		mins.	mètre.	mètre.	m^2.	
23 July	Wrangel Sohle III	135	2,00	2,80	5,60	
24 "	"	105	2,15	2,55	5,48	
25 "	"	105	1,80	2,55	4,59	3 knives broken.
26 "	"	120	2,00	2,60	5,20	1 knife broken.
27 "	"	120	2,00	2,60	5,20	

The following are authentic results of cutting in hard coal:— Three men look after two machines, and accordingly the average cost for holing, taken from the above figures and assuming the seam to be 3 feet thick and the rate of wages at 7*s.* 6*d.* per day as before, in a working shift of 8 hours, two machines will hole across a face 122·8 feet, 6·3 feet under, which is equivalent to 50 tons of coal, the rate per ton for wages being 5·4*d.*, or exactly double the amount of that upon the bar and disc machines noticed. The capital outlay is, however, very much below the previously estimated machines, consequently the charges for interest, depreciation, etc., work out at about the same on every ton of coal produced, and so the cost of holing may be put down at 2·7*d.* above them. By the Frölich system the rate per ton will then show a saving of 3·86*d.* as against 6·56*d.* by the Bar-type machine and the two disc-type machines mentioned; but the Frölich machine has special advantages which discount the gain in favour of other types as shown. Four machines are better than one, they are easier to handle, and they take about five minutes to fix up for work; no rails are required, and, an important consideration, existing conditions at the mine need not be interfered with. Thus where longwall or pillar and stall is worked, the machine applies; heading work and cross cuts are dealt with as readily, and the fact of less space being occupied is a good feature.

When coal-cutting by machinery is efficiently carried out, the working face is kept straight and clean. Under-cutting to greater depths than is possible by hand renders the requisite timbering less frequent and therefore less costly, and also a reduction in the number of shots to be fired is found from experience to be considerable. By keeping a straight line the coal breaks away more easily, especially when aided by increased depth of hole. At a mine in Yorkshire forty shots were fired per day, when the holing was made by hand; the machine method reduced the number of shots necessary to seven.* Another good feature in the new method to be noted is, that work can be carried on regularly; to keep a face moving forward at a set speed, varying conditions are minimised, and so the work becomes easier to cope with and less hazardous.

* This result is due to deep under-cutting by machines at Messrs. Pope and Pearson's, Normanton.

Summary.—In some instances, the estimates given may appear understated and in favour of mechanical methods. Inquiry will, on the other hand, discover the leading points are shown in an unfavourable light to coal-cutters; the 2*s.* 6*d.* rate is undoubtedly below the average of hand work. However the author hopes to have established a tangible advantage in the use of mechanical means, and that the amount suggested as the possible all-round reduction in the cost of producing coal is within the reach of a large majority of our mine owners. Further gains might be established by the use of power drills; good work has been witnessed by the Frölich Rock Drill and the Daw Rock Drill, both of which are percussive machines, and the Elliott Rotary Drill, Fig. 6. The question of determining

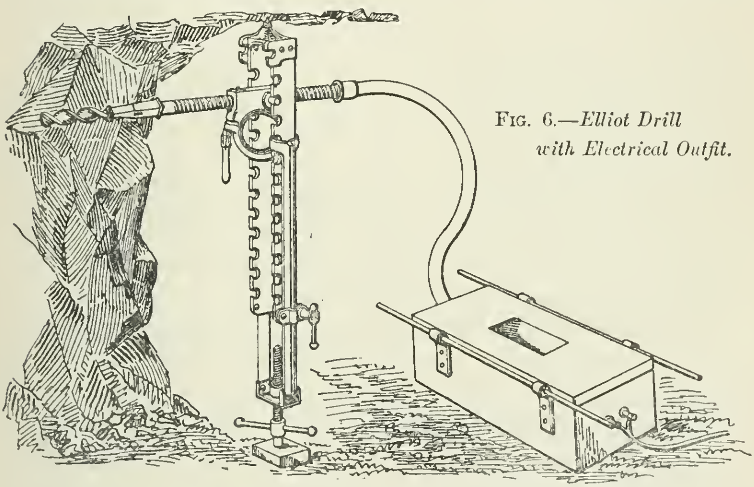


Fig. 6.—*Elliot Drill with Electrical Outfit.*

relative results of hand work versus power is complex however, and almost impossible, as singular cases would have to be taken, which when demonstrated would prove next to nothing. However, there is a substantial gain to be effected in this direction.

Figures are reputed to have the quality of proving almost any set idea. The author hopes those set down in the preceding pages will be taken seriously; if they fail, the suggestion of a local engineer might be quoted. He remarked, to prove the real value

of coal-cutting and drilling machines, that a number of collieries should combine together, and, after selecting the most suitable type to meet each particular case, put in one cutter, with other mechanical tools to work a district; that is, each mine should set apart a district to be worked exclusively under mechanical methods, say for a year, each pit working independently, with a view to ultimately, after the expiration of the term, comparing notes and reporting results. If such a plan were possible, the idea could be effectively settled for or against, and the results would in the author's opinion show fully the advantages which are set down in this Paper as being more than possible.

Conclusion.—Too much cannot be said on this subject, for the all-important reason of its bearing such a serious and far-reaching effect upon those trades kindred to mining, as well as upon the prosperity and future of this country; and if the author has not proved beyond doubt real and tangible results, he may at all events have opened out to some extent a question which must ultimately be taken up vigorously. Whatever may be the future of mechanical coal-cutters and other appliances in mines, there is the assuring fact to be remembered in considering it, that there is not a single drawback to its adaptation, from the point of view of safety to life or the science of mining engineering.

From the practical point of view, some objections to machine practice occur; they present themselves differently in each mining district, discussion may indicate them variously. One of the chief objections to the system is the difficulty in finding men to attend the machines, possessing sufficient mechanical skill and pit experience to enable them to cope with contingencies at the face as they are met; but this hardly reflects discredit upon the mechanical methods directly. Miners can readily apply themselves, if dealt with with tact and encouraged in the work. At some places machine methods have recorded a failure, traceable very often to the plant being either badly designed or lacking the necessary power, but most often to the system being taken up in a desultory manner, for it seldom happens that a new idea does not meet serious difficulties, due to prejudice, either on the part of the management or the men.

Percussive Rock-Drills.—The introduction of a driller into the category of coal-cutting appliances will no doubt cause a little surprise; the arrangement for swinging the tool whilst operating shows, however, that holing under or in coal can be performed, and under certain conditions exceedingly good holing, for instance, in places where a conglomerate is met which cannot be dealt with by a rotating action, the percussion rock-drill does the work satisfactorily; in fact, a percussion machine often does well when other types completely fail. The swinging device allows the tool to be worked at varying angles from the horizontal to a vertical position, so it can hole under and shear, and therefore applies to many conditions of a coal-cutter proper. The Frölich machine, Plates 70 and 71, is more serviceable for heading purposes and drilling. The illustrations show the chief points in the machine and the methods of heading operations, which are very interesting. Various sizes are made; the one for general work is as follows:—Cylinder 3 inches diameter, varying stroke from 6 inches to 8½ inches, working pressure 2½ to 4 atmospheres, number of strokes per minute 300 to 400, weight 180 lbs. A hydraulic column, Fig. 5, Plate 71, is used mostly, which arrangement gives a much firmer hold to the work than an ordinary screw. It is said that two and three machines are fitted on to one column, but this could not be in a coal mine; in sinking operations the machine is fitted on a tripod.

The Frölich Drill is made in four sizes as follows:—

No.	Diameter of Piston.		Maximum Stroke.		Weight.		Pressure in Atmospheres.	Approximate Horse-power required per Machine.
	mm.	ins.	mm.	ins.	kg.	lbs.		
1	80	3·15	220	8·64	130	286·60	2½ to 4	8 to 13
2	75	2·95	220	8·64	90	198·41	„	7 „ 12
3	70	2·75	190	7·46	85	187·39	„	6 „ 10
4	60	2·36	170	6·98	70	154·32	„	5 „ 8

There are many power drills to be seen working on the Continent and in this country, notably the Daw Rock-Drill, made by the Hardy Patent Pick Co., which firm probably have had more experience in this direction than anyone. They also make a power rotary machine for general drilling work in coal and ironstone; it is in reality the well-known Elliott Drill, Fig. 6 (page 555), with an electric motor and outfit attached—a handy tool, very light.

Mr. Morison, of Cramlington, has recently invented a double-cylinder percussion drilling-machine which has very remarkable features, and it may be seen working at Cramlington. He proposes to use this tool for holing purposes as well as drilling.

Bar-Type Coal-Cutter (*Hurd*).—This machine is a little less costly to install, and it is said less power is required and it occupies less space as compared with disc machines; all things considered, there is no material gain by this type over the disc machines when account is taken of work performed. Like the disc cutters, they are designed to work on the floor-level and at varying heights above the floor. Plate 72 illustrates an under and over type machine, which shows it to be a compact and altogether a sound mechanical engineering job. Doubt as to the ability of the bar standing up against heavy work may be dispelled, as it seldom if ever happens that this part gives way; the cutting tool is rather a difficult thing to shape, but by the use of proper forging dies this work can readily be performed at an ordinary blacksmith's hearth. The Table on page 559 shows the principal dimensions and other interesting details.

The cutting tools, Fig. 9, Plate 72, are all one size, that is, one size from one end of the bar to the other; they weigh ½ lb. each; picks are fitted at intervals between the screw, and the bar rotates at about 400 revolutions per minute. In the cutter head-piece there is a toggle arrangement which gives the bar a reciprocating action; this back and forward action, together with the rotary motion, gives a shearing and chipping action on the coal, which reduces the strain on the bar, and effectively cleans out cuttings from the tools themselves. The cutter head-piece has special advantages in the ready way of varying the angle of the holing bar. The bar may be tilted to any

angle. The small size (A) is applicable to low seams, owing to its light weight and the space it occupies.

Disc-Type Coal-Cutter (*Clarke-Stephenson*).—Generally the disc machines are larger than the Bar machine described; they are heavier and occupy a little more space, but against the apparent disadvantages there are the questions of stiffness and a greater output to be considered. The Clarke-Stephenson, Plate 73, is doing work

No.	Length.	Width.	Height.	Weight.	Weight of Bar.	Undercut.	Power.	Continuous Current.	Gauge of Rails.	Weight of Rails.
				cwts.	cwts.		B.H.P.	volts.		lbs. per yard.
A	6·6	2·6	1·1	19	1½	2·6 to 3·6	12	400	1·6 to 2·3	22
B	9·3	2·8	1·4	30	2½	3·0 to 4·6	18	,,	1·9 to 2·4	25
C	9·6	2·8	1·10	45	3	4·0 to 6·0	26	,,	2·0 to 2·4	28

equally as well as any other coal-cutting machine; the disc is made of cast-steel to undercut from 3·6 to 6 feet; cutter tools are fitted to the periphery of the disc about 12 inches apart into a square socket set to a suitable angle, and there are also provided sockets to opposite hand, thereby allowing the machine to hole across a face in either direction by the simple re-adjustment of the tools and reversing the engine and hauling tackle. The disc has teeth grid-fashion cast on the internal part of the rim, into which is geared a pinion. A single motor (continuous current) is fitted, and with intermediate gearing the speed is reduced. The disc revolves at varying speeds from 20 to 50 revolutions per minute, to suit the work to be done; the motor, which is capable of developing 25 Eff.H.P., runs about 900

revolutions per minute. The drawings, Plate 73, which are supplied by the makers, Messrs. Ernest Scott and Mountain, are concise, and go to show that the designs are carefully considered, due regard being shown to lightness consistent with stability. The Clarke-Stephenson machine is fitted with the Scott and Mountain totally enclosed electric motor.

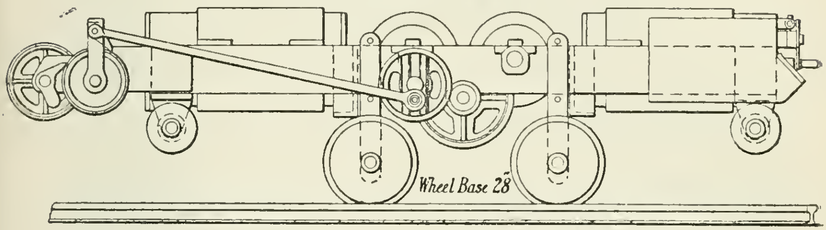
Disc-Type Coal-Cutter (*Diamond Co.*).—These coal-cutters are made to work electrically and by compressed-air; they have many points in common with other machines of the disc-type, but the cutting disc is arranged to work from a central point, and where it is advisable to hole across the face and back alternately this seems the better form. The machine is always in perfect balance, and naturally greater depths of under-cutting can be obtained without the risk of the trouble of getting off the road. The disc is provided with loose or separate tool-holders fitted to lugs projecting from the rim—a very good feature, as it simplifies the disc casting, and the tools can more readily be reversed; a bolt is withdrawn and the tool-box reversed.

The electric appliance does not seem as simple as the one previously noticed, there being two motors fitted in series, but probably less heating at the armatures is found, owing to the cooling area being greater; in many other respects the two disc machines compare.

The compressed-air machine is probably the best of its class in use at present; the central position of the disc most likely found its origin in the compressed-air type; it applies perfectly both to the engines and to the gearing, two cylinders being placed one at either end of the framing and driving on to a central shaft. The application of compressed-air has advantages over that of electricity, the speed of the engines being more suitable to the working speed of the tools; reducing gear is thus almost done away with—in fact, the crank-shaft may be coupled direct to the disc through a single purchase. As to the question of safety, this is somewhat exaggerated. Electric appliances of the present day for mines are quite safe, the motors are so well covered that a spark cannot possibly be emitted, the only source of danger being the possibility of a cable being dislocated; there are many such

incidental possibilities in a mine, although very remote. Plates 74 and 75 show the machine as it is now made, and Fig. 16 shows the arrangement for flitting the machine. An electric machine of this

Fig. 16.—*Arrangement for Flitting the Machine.* (Diamond Co.)



type possibly holds the record for holing, namely, at a pit in Durham, where 140 yards nearly 6 feet deep is cut per shift, representing an average of 2,500 superficial feet.

The Paper is illustrated by Plates 70 to 75, and 2 Figs. in the letterpress, and is accompanied by 2 Appendices.

APPENDIX I.

Heading work records by the Frölich Drill, Plates 70 and 71.

Driving a heading at the "Mansfeld'schen Kupferschieferbauende Gewerkschaft," Shaft "81 *Lichtloch," near Klostermansfeld.*

Four Drills in use.

Time required to complete the work—From 19th October to 16th December 1899.

Length of heading done	2120 feet.
Section of heading	9 feet wide by 7½ feet high.
Character of rock	Magnesia Limestone and Lower New Red Sandstone.
Number of working days	134.
,, ,, attacks	713.
,, ,, drills in use	4.
,, ,, hydraulic columns in use . .	2.
,, ,, miners per shift	8.
,, ,, drivers	9.
Average number of bore-holes per attack . .	9.
,, depth of bore-holes	3 feet 7 inches.
,, time for drilling the bore-holes . .	1 hour 46 minutes.
,, ,, ,, blasting and carting . .	2 hours 28 minutes.
Gelatine dynamite used per attack . . .	25 lbs.
,, ,, ,, ,, linear foot of heading	8 ,,
Average progress per attack	3 feet.
,, ,, ,, 24 hours . . .	15 feet 10 inches.

Driving a heading of the "Kirchbergtunnel" near Schiltach (Schwarzwald).

One Drill in use.

Time required to complete the work—From 29th December 1891 to 3rd of February 1892.

Length of heading done	127 feet.
Section of heading	6½ feet wide by 7½ feet high.
Character of rock	Hard Granite.
Number of working days	28.
,, ,, attacks	40.
,, ,, drills in use	1.
,, ,, columns in use	1.
,, ,, miners per shift	2.
,, ,, drivers ,, ,, ...	3.

Average number of bore-holes per attack .	11.
,, depth of bore-holes .	3 feet 5 inches.
,, time for drilling the bore-holes .	11 hours 45 minutes.
,, ,, ,, blasting and carting .	5 ,, 25 ,,
Gelatine dynamite used per attack .	20 lbs.
,, ,, ,, ,, linear foot of heading	$6\frac{1}{2}$,,
Average progress per attack .	3 feet 2 inches.
,, ,, ,, 24 hours .	4 ,, 7 ,,

Driving a heading at the Coal Mine "Deutschland" near Hasslinghausen.

Two Drills in use.

Time required to complete the work—From the 26th of October 1894 to 26th of June 1895.

Length of heading done .	1,590 feet.
Section of heading .	8 feet wide by 7 feet high.
Character of rock .	Hard Sand Stone and Slate Rock.
Number of working days .	199.
,, ,, attacks .	342.
,, ,, drills in use .	2.
,, ,, hydraulic columns in use .	2.
,, ,, miners per shift .	4.
,, ,, drivers ,, ,, .	2.
Average number of bore-holes per attack .	17.
,, depth of bore-holes .	5 feet 1 inch.
,, time for drilling the bore-holes .	6 hours 30 minutes.
,, ,, ,, blasting and carting .	7 ,,
Gelatine dynamite used per attack .	42 lbs.
,, ,, ,, ,, linear foot of heading	9 ,,
Average progress per attack .	4 feet 8 inches.
,, ,, ,, 24 hours .	8 feet.

APPENDIX II.

Cost of Getting Coal in a South Yorkshire Colliery.

Total *underground cost of working* a seam 3 ft. 3 in. at a depth of over 500 yards in a Yorkshire Colliery, by means of the "Diamond" deep undercutting machine, holing to a depth of 5½ feet in stiff fireclay.

	Cost per ton. s.	d.
Coal getting (11*d.* per ton standard price, including 57½ district percentage)	1	6·46
Coal-cutter men, paid by day		4·82
Cleaning up, ripping (9 feet roads), horse-keepers, hurrying and hanging on, main roads, bye work, and superintending, including deputies, shot-firers, etc.	1	1·91
	3	1·19

Approximate output from seam, 4,500 tons per week.
Average tonnage for fillers, 6½ tons per shift.

Discussion.

The President proposed a vote of thanks to Mr. Wainford for his excellent and suggestive Paper, which was heartily accorded.

Mr. R. Hood Haggie referred to the fact that there were about 4,000 machines in America, of which forty-eight were longwall machines, which were very much heavier to work than the percussive drills, and he thought that showed why America had advanced so far with machinery. The Americans had gone in for heading machines, and with the easier worked machines they had gone ahead much more than we had in this country. He agreed that the use of machines led to a smaller number of accidents, but thought it would be still better if makers would endeavour to reduce the noise in the

machines, so that the miners could be warned in time by hearing the roof cracking. There was no mention in the Paper of the Jeffrey machine which had the gearing running in oil, and was so silent that the roof could be actually heard cracking when any moderately loud cracks took place.

With regard to heading machines, there was no mention about the chain-heading machine, which did its work much more quickly than the percussive drill. It was possible to undercut 6 feet in a heading 9 inches wide, in three moves across the face, fix and take the machine away in under the hour, so that the rest of the time might be used for blasting and clearing out the coal. There was rather an interesting point about the percussive drills. At the Cannock and Rugeley Collieries there was a percussive drill, and it was found that in the side cutting, by having the tool with eight points on it, it cleared itself better, but in the hard ground it only required three points, but even then it was pretty slow work compared with a chain-heading machine.

The author stated (page 560) that "Electric appliances of the present day for mines are quite safe, the motors are so well covered that a spark cannot possibly be emitted, the only source of danger being the possibility of a cable being dislocated ; there are many such incidental possibilities in a mine, although very remote." He did not think it was quite fair to instil into the colliery manager's mind that the possibility of a cable being broken was remote. It was not remote ; it was a very probable thing to happen in the pit, and the greatest care must be taken, otherwise the whole place might be wrecked. There was no doubt that electricity was the power to be used for coal cutters, but managers of coal mines should understand that there was a danger and that all possible care must be taken. People spoke far too easily of taking electricity into mines. He did not know the "Frölich" drill mentioned in the Appendix, and shown on Plates 70 and 71, but the averages did not seem to work out very well. The undercutting was only 3 feet, whereas the percussive drill should undercut 12 feet in a 9-foot heading. He did not think it was such a satisfactory thing, however, as a chain-heading machine such as was used largely in America.

Sir Benjamin C. Browne said he was connected with one colliery that had adopted coal-cutting machines, and he could certainly bear witness to their great financial value. It used to be general, when a colliery was valued, to assume that the profit on the coal ought to be 1*s*. a ton, that was to say, it was fair to assume on the part of the colliery that the owner ought to be able to sell the coal for 1*s*. a ton more than it cost him. If it was possible to save a 1*s*. a ton by using the machines, it simply meant that a large number of collieries might go on being worked which would otherwise be closed, and a number of seams would become valuable which were not so now, and in that way the actual quantity of available coal in England, or in any other country where the machines were adopted, would be added to. He was not aware that there were any serious drawbacks to them. He thought it was necessary to work with them on the longwall system, and where the longwall system was not available, he understood that the machines were not applicable. On the whole, he believed that the machines were coming to stay, and were a great success in the trade.

Mr. Sydney F. Walker said the subject was a very vast one, and thought the author had only touched the fringe of it. He had rather mistaken the point with regard to obtaining cheap fuel. It was not the iron industry or engineering industry in this country which was going to be wrecked by collieries not producing cheap fuel; it was the coal industry. The danger was that the Americans would do with the coal industry what they had done with the wheat industry. They were in the position which our collieries were in fifty years ago, and they would produce cheap coal and deliver it at our iron and engineering works, unless our collieries were up and doing and brought the cost down. In America the collieries were all working from shallow seams, working on the cheap bord and pillar system, and they had a great many advantages which were not found in this country.

Coal-cutting by machinery had come to stay, and he thought everybody in the colliery world was very well satisfied with the advantages of coal-cutting by machinery. The difficulty was as to

whether it might be applied, when it could be applied, and how it could be applied. One great difficulty the last speaker had referred to; a very large quantity of coal in this country was worked on the bord and pillar system, and there was no machine which was capable of working economically on bord and pillar coal. On the other hand, bord and pillar was giving way gradually to longwall, for the purpose of the application of coal-cutting machines. In America they were working a modified form of bord and pillar—stoop and room they called it, as they did in Scotland—but they made their rooms 20 feet wide, and in their later practice they were making the rooms 60 feet wide and working a sort of bastard longwall machine on the 60-foot face. He did not think there was much to fear from America if this country was able to adopt coal cutting right away through. One of the difficulties in the way of the adoption of coal-cutting machines was low cutting-prices in certain cases by hand labour. In the inquiry he made, the substance of which was given in his book, he came across one record cutting price of 6*d.* a ton by hand. It was difficult to put down £1,000 worth of machinery, and show economy at 6*d.* a ton. In the very thick coals of South Staffordshire the coal-cutting machine was difficult to apply and also in the South Wales coal, because in the steam-coal measures the coal almost came down with looking at it. On the other hand, in the thin coal seams the advantages came in immediately. He had one record case, a very special case, in which a seam of 3 inches in depth was got out by a machine. The cutting price by hand had been 20*s.*, but it was reduced to 10*s.* a ton. It was a very valuable seam, and that reduction in price enabled it to be placed on the market. There was a colliery in Yorkshire in which a seam 18 inches deep was worked by a Diamond machine, in which the total saving was something like 7*s.* a ton, and that enabled the colliery to be worked at a profit, whereas before it could not be so worked. There were two advantages in working by machines, one was the lower cutting cost, and the other the less amount of small which was made. The working collier in undercutting the coal had to provide sufficient room to get his head and shoulders in, and therefore he cut away a very much larger quantity of coal into small than the machine did, which cut a

(Mr. Sydney F. Walker.)

parallel groove. He made out in his inquiry that the average was a reduced cost of 1*s.* a ton, and an increase selling value of 1*s.* a ton; that was the average. There were a great many cases where there would be neither an increased sale nor decreased cutting piece, but there were a great many cases where the two were very large. He did not think the author appreciated the fact that during recent years the coal-cutting machine had been applied to thicker seams by deep undercutting. By undercutting a thicker seam sufficiently deep, to provide sufficient leverage on the overhanging coal to bring it away from the strata above, working the coal so that the break would follow the natural line of cleavage of the coal in every case, it might be possible to do away with a large number of shots which would be otherwise fired, and in some cases it had been practicable to entirely eliminate shot firing. That was a matter of enormous importance, because every shot fired in the pit, notwithstanding the great safety with which it had been carried out, was a possible cause of explosion. It was not necessarily only in cases where gas was imprisoned in the coal gas; in dusty mines an explosion might occur from the ignition of the coal dust.

The next question was, what was the type of machine suitable for British collieries? As far as his inquiries went, it was the disc machine. There were two machines before colliery owners for longwall working; the heading machine, which one speaker referred to, was used for cutting headings, and used largely in America for stoop and room practice; the bar machine and disc machine were the only machines on the market for longwall work. The bar machine was apparently the ideal machine; it took less power and worked very much better. But there were very many things which came in the way, one being that nature in laying down the coal seams, and the fire-clay underneath, had not done it uniformly. She had very often placed balls of pyrites in the way, and when a ball of pyrites was reached, it had either to be dug out or gone around. The bar machine could not be trusted to dig it out, whereas the disc machine did. The consequence was that in the bar machine it was necessary to provide extra gearing to enable the bar to shirk the obstacles. Again, the bar machine must not be allowed to cut straight; it must

have a reciprocating motion, or it would lock itself and the cutters would get very hot. The consequence was that, when cutting in the dirt, the reciprocating motion carried the dirt into the gearing, and the repairs bill for the bar machine was very heavy in consequence. In the inquiry he made, he was shown one set of cost sheets very carefully got out. He was not allowed to give the name or the amounts, but they were heavy indeed—sufficient to wreck the use of almost any machine, and that for a colliery where the machines were stated to have been used successfully. On the other hand, it was fair to say that the bar machine in one or two cases had done very good work. He heard of a case in the neighbourhood of Llanelly where the manager told him he was cutting under a seam 18 inches thick and doing very good work, but his men were on strike against the machine.

In one case he came across a disc machine which had been taking 100 H.P. for a short time while getting out a ball of pyrites, and it did it well. The disc machine had been developed from the original Gillett and Copley. The Gillett machine at work now was still doing very good work, a light machine weighing only 15 cwt. The next step was to make the machine larger and heavier, and then to adapt an electric motor to it as in the Clarke and Stephenson and Yorkshire Engine Co. It was the Clarke and Stephenson which was taking the 100 H.P. and dragging out a ball of pyrites. There was a difficulty with the machine, having the disc at one end and the motor at the other—whether it was an electric motor or a pair of engines worked by compressed air, the disc dragged the machine in towards the coal, and something was required to keep it off. That something took the form of a bridle on the rails, which gave a certain amount of trouble. The next development, and it appeared to him the natural one, was the division of the power. Two cylinders were put on, one at each end of the machine, with the disc in the middle. The electric motors were also divided and put one at each end, worked in series, and incidentally there were a number of advantages. The bridle was done away with, and the machine was perfectly balanced, and would cut either way. It was possible to do

(Mr. Sydney F. Walker.)
what one liked with it, as far as working in a colliery was concerned.

The electrical conditions raised some very important points. A 15-H.P. armature was very much smaller than a 30-H.P. armature. Having the armature very much smaller, with very nearly the same space to play with for the 15-H.P. machine as for the 30-H.P., it was possible to devote a large quantity of the space to insulation, and as was well known insulation was the weak point of all electrical apparatus. Insulation was always weak mechanically; it always allowed a certain amount of current to pass through, leading to the passage of sparks later on, and so on, and if it was possible to reduce from 500 volts to 250 volts, the chances of keeping the machines going were approximately multiplied fourfold. The additional space also enabled the motor to be enclosed more securely, and gave a larger radiating surface to get rid of the heat which was unavoidably generated. There was another advantage in deep undercutting. By cutting 5 feet 6 inches or 6 feet under, there was practically half the number of settings of timber, half the labour cost, and a largely increased factor of safety in the roof. In the case of the roof there was a time factor. If the roof went forward quickly, there was a much better chance it would stand until the men got well out of the way, than if it was dragging along as it was with the irregular cut and shorter cuts possible with hand-labour.

Sir LOWTHIAN BELL, Bart., Past-President, said he had listened with considerable surprise to the opinions enunciated by the last speaker. According to that gentleman our collieries were threatened by annihilation by coal which was to be brought from the United States to Great Britain. The furnace works with which he was connected required 2,000 tons of coal a day, and were probably using 500 tons more in working pig-iron into steel. The cost of running a steamer from this country to America might be taken at about 6*s.* a ton out and home. Supposing that there was as much weight coming from the United States as was sent from this country, the cost of carrying the ton of coal from this country might be taken as 3*s.* It would be far more than that, because there was a greater

weight of material coming from the United States than there was of English produce going in a contrary direction, and he pitied the position of his firm, and of every other ironmaster and steel manufacturer in the country, if a day should ever come when they had to bring their coal from the United States.

Communications.

Mr. R. HOOD HAGGIE wrote that, with reference to Mr. Sydney F. Walker's statement (page 567) that there were no heading machines working satisfactorily in this country, it was only right that attention should be drawn to the Jeffrey Chain Heading Machine, driven by either compressed air or electricity, and supplied by Messrs. John Davis and Son, of Derby. There was a large number of these at work in this country, and in every case they have given complete satisfaction. Fig. 16, Plate 76, showed one driven by compressed air, and Fig. 17 one driven by electricity. The same firm have also got a longwall disc coal-cutter driven by either power, and these differed in one or two points from those mentioned in the Paper, and so should be recorded. (1) The machine ran on one rail only, so that there was no strain on it, should the disc run up into the coal or down into the pavement. There was also more room for the cuttings out of the kerf. (2) The movable rocker arm to which the quadrant plate was attached, so that the man in charge could suit the cutting to the hills and hollows in the floor. (3) The gearing was all enclosed and running in oil in the electrically driven machine, so that the noise was reduced to a minimum. (4) The man in charge of the machine could work every thing from the front of it, and so was further out of danger by being under a better supported roof; in this point the "Hurd" machine seemed to be similar.

Mr. WAINFORD, in reply to the discussion, wrote that it was a matter of regret that owing to the expiration of time the discussion had to be closed, as there might have been expressions made relative

(Mr. Wainford.)
to the question of economy, which was the intrinsic object of the Paper. Sir Benjamin Browne, in his remarks, touched most closely that question, and it was with extreme pleasure the author learnt that his experience coincided with the Paper as to financial benefits in the use of machines at the coal face. In further reply to Sir Benjamin, the author agreed that the longwall system was best suited to machine practice, but substantial gains were possible in other systems of coal-getting by the adoption of heading machines, such as the Jeffrey chain type and percussive drills as described. Mr. Hood Haggie (page 564) stated that there were but 48 longwall machines out of the 4,000 coal-cutters at present operating in America—a fact which argued strongly in favour of heading machines. Mr. Haggie referred to the Frölich drill as only undercutting 3 feet, which was not correct. The maximum depth was $2\frac{1}{2}$ metres, but this was only attained by changing the drill two or three times; this depth was ample under most circumstances.

As to the Jeffrey chain machine, Plate 76, referred to by Mr. Hood Haggie (page 571), the author could only express regret that he was unable to accept invitations extended to him to witness them operating.

The same speaker (Mr. Hood Haggie) raised a question of the utmost importance to miners, when he mentioned the noise created by machines, and it should be the primary object of all manufacturers of coal-cutting machines to reduce this to a minimum at whatever cost. With regard to electrical appliances—Mr. Haggie made rather too much out of the remarks (page 565); it was not the author's intention to treat lightly the responsibility of adopting them in coal mines—where carefulness must always be the very first consideration, but merely intended to convey an idea that electrical engineers designed appliances to meet the exacting conditions as required.

Mr. Sydney F. Walker in his opening remarks (page 566) said he thought the author "had rather mistaken the point with regard to obtaining cheap fuel. It was not the iron industry or engineering industry in this country which was going to be wrecked by collieries not producing cheap fuel; it was the coal industry. The danger

was that the Americans would do with the coal industry what they had done with the wheat industry." In this matter the author totally disagreed, and must strongly adhere to what was set forward in the Paper; the wheat analogy did not apply. Foreign countries, especially America, would prefer to send into our markets finished goods to raw material, for the very simple reason there was more to be made out of them, and although it might be true that coal could be delivered from America at as low a price as we could produce the same material, they would never seriously try to establish a market for it. If they did so, it would have the stimulating effect of hurrying us up to producing coal on more economical lines, and then they would be defeating their own ends; besides, with the very substantial margin of 3*s.* a ton or more, as indicated by Sir Lowthian Bell (page 570), being the freightage, such a competition could always be held in check; but, on the other hand, which was the point contended, by having a cheaper fuel iron, steel and engineering work was produced at reduced prices, as shown by the amount of fuel used in the manufacture of such work. They would be content therefore to go on as they were doing, namely, competing successfully with the kindred trades.

Mr. Walker (page 567) gave some very valuable information from his own experience of the use of mechanical appliance at the coal face, and it was pleasing to the author to note that he was generally in agreement with the Paper upon the all-important element of economy.

The author tendered his thanks to the President, to the speakers, and the members for the kindly interest taken in his initial contribution, and sincerely hoped it had proved of some value.

In reply to Mr. Hood Haggie's communication (page 571), the author was pleased to note that attention had been given to the serious objection of noise caused by the coal cutters in the machines he (Mr. Haggie) referred to. Another good feature was referred to in the communication, namely the fact of the attendant being in front of the machine, whilst working; this was certainly the safest position.

EXCURSIONS.*

On Tuesday Afternoon, 29th July, after luncheon in the Old Assembly Room, by invitation of the Local Committee, the Members were conducted round the Elswick Works of Messrs. Armstrong, Whitworth and Co., under the guidance of the officers of the Company.

The following Works were also open to the visits of the Members on the same afternoon, and during the Meeting :—

Abbot and Co., Park Works, Gateshead.

Atkinson and Philipson, Coach Works, 27 Pilgrim Street.

Backworth Coal Co.'s Collieries, Backworth.

Burradon and Coxlodge Coal Co.'s Collieries, Gosforth.

Co-operative Wholesale Society's Flour Mills, Dunston.

Durham College of Science, Engineering Laboratory, Barras Bridge.

Hawthorn, Leslie and Co., Locomotive Works, Forth Banks; Marine-Engine Works, St. Peter's; and Shipyard, Hebburn.

Newcastle-upon-Tyne and Gateshead Gas Co.'s Works at Redheugh, and new Gasholder at Walker.

Newcastle and District Electric Lighting Co.'s Power Station.

North Eastern Railway Co.'s Locomotive Works, Gateshead.

North Eastern Railway Co.'s Locomotive Works, Darlington.

North Eastern Railway Co.'s Middlesbrough Docks, and Electric and Hydraulic Power Station.

North Eastern Railway Co.'s Tyne Dock and Coal Staithes.

John Readhead and Sons, South Shields.

R. Robinson and Son, Printing Works, Clavering Place.

John Rogerson and Co.'s Works, Wolsingham.

Scott and Mountain, Electrical Works, Close Works.

Robert Stephenson and Co., Shipyard, Hebburn.

Rolled Weldless Chain Co., Blaydon-on-Tyne.

United Alkali Co.'s Sulphur Recovery Plant, Allhusen's Works, Gateshead.

Walker and Wallsend Union Gas Co.'s Sub-Stations, Walker.

Wallsend and Hebburn Coal Co.'s Collieries, Wallsend-on-Tyne.

---

* The notices here given of the various Works, &c., visited in connection with the Meeting were kindly supplied for the information of the Members by the respective authorities or proprietors.

In the evening the Institution Dinner was held in the Grand Assembly Rooms, Barras Bridge. The President occupied the chair; and the following Guests accepted the invitations sent to them, although those to whom an asterisk (*) is prefixed were unavoidably prevented at the last from being present.

The Right Worshipful the Mayor of Newcastle-upon-Tyne Alderman Henry W. Newton, Chairman of Reception Committee; Sir Benjamin C. Browne, D.C.L., Convener, Reception Committee; *Sir Thomas Richardson, Convener, Reception Committee; Dr. R. Spence Watson, President, Literary and Philosophical Society; Sir Lindsay Wood, Bart.; Mr. H. I. Brackenbury, Honorary Secretary, Reception Committee; Mr. E. L. Davis; Mr. Charles Hopkinson; Mr. W. D. Hunter.

Newcastle Reception Committee.—Mr. B. G. Arkwright; Mr. W. I. Armstrong; Mr. Charles Baister; Mr. T. C. Billetop; Mr. William Black; Mr. William Boyd; Mr. John Bulmer; Mr. Henry Carrick; Mr. Ambrose C. Casebourne; Mr. Walter A. Clatworthy; Mr. A. H. J. Cochrane; Mr. P. N. Collyer; Mr. Arthur Coote; Mr. W. E. Cowens; Mr. J. C. Dickinson; Mr. W. J. Douglass; Mr. John Duckitt; Mr. F. J. Edge, City Engineer; Mr. Alfred L. Forster; Mr. Henry Fownes; Mr. Edwin Griffith; Mr. Arthur Gulston; Mr. C. A. Harrison; Mr. J. H. Heck; Mr. Robert Hedley; Mr. John H. Holmes; Mr. George L. Hunter; Mr. M. C. James; Mr. John Jameson; Mr. Ramsey Kendal; *Mr. R. O. Lamb; Mr. Henry Lawrence; Mr. William Mills; Mr. W. C. Mountain; Mr. R. H. Muir; Mr. David Myles; Mr. Edwin L. Orde; Mr. C. Faraday Proctor; Mr. Vincent L. Raven; Mr. Robert Readhead; Mr. J. W. Reed; Mr. Joseph M. Rennoldson, J.P.; Mr. J. Cartmell Ridley; Mr. H. L. Riseley; Mr. A. E. Le Rossignol; Mr. H. B. Rowell; *Councillor William John Sanderson, Sheriff; Mr. J. H. Smeddle; Mr. Walter M. Smith; Mr. Wasteneys Smith; Mr. W. G. Spence; *Mr. J. W. Spencer; Mr. Arthur C. Stamer; Mr. H. G. Stobart; Colonel Henry F. Swan, J.P.; Mr. M. W. Swinburne; Mr. John Trail; Mr. John Tweedy; Mr. R. H. Wainford; Mr. Henry Walker; Mr. John Wallace; Mr. Robert Wallis; Mr. H. Burnett Watson; Mr. T. J. Watson; Mr. J. G. Weeks, President, North of

England Institute of Mining and Mechanical Engineers; Professor R. L. Weighton; Mr. W. A. Woodeson; Mr. P. B. Woodger; Mr. W. B. Woodhouse; Mr. Wilson Worsdell; Mr. James Young; and Mr. Robert Younger.

Sunderland Reception Committee.—*The Worshipful the Mayor of Sunderland, Alderman J. G. Kirtley; Mr. F. M. Bowey, Town Clerk; Mr. J. F. C. Snell, Chief Electrical and Tramway Engineer; Mr. H. England, General Manager, Sunderland Corporation Tramways; Mr. D. H. Haggie, River Wear Commission; Mr. C. H. Dodds, Manager, River Wear Commission; Mr. J. G. Morris, River Wear Commission; Mr. H. H. Wake, Engineer, River Wear Commission; Mr. R. A. Bartram; Mr. W. L. Byers; Mr. F. T. Dickinson; Mr. R. P. Doxford; Mr. W. H. Dugdale; Mr. G. Hands; *Sir John Jackson, F.R.S.E.; Mr. Hugh Laing; Mr. J. Marr; Mr. Lynn Marr; Mr. M. W. Parrington; Mr. Easton R. Kirkley; Mr. R. J. Smith; Mr. W. Thackray; and Mr. G. D. Weir.

The Hartlepools Reception Committee.—Mr. W. C. Borrowman; Mr. W. T. Cheesman; Mr. Ernest H. Craggs; Mr. J. C. Harding; *Mr. D. B. Morison; *Mr. Tom Westgarth; Mr. J. Begby Williams; and Mr. J. R. Fothergill, Honorary Local Secretary.

The President was supported by the following Officers of the Institution:—*Past-Presidents*, Sir Lowthian Bell, Bart., LL.D., F.R.S., Sir Edward H. Carbutt, Bart., Mr. E. Windsor Richards, and Mr. Percy G. B. Westmacott; *Vice-Presidents*, Mr. John A. F. Aspinall, Mr. Edward P. Martin, *Mr. A. Tannett-Walker, and Mr. J. Hartley Wicksteed; *Members of Council*, Mr. Henry Lea, Mr. Mark Robinson, and Mr. John Tweedy.

In proposing the health of "The King," the PRESIDENT made a sympathetic allusion to His Majesty's illness, and the toast was most enthusiastically honoured, as was also the toast of "The Queen, the Prince and Princess of Wales, and the other Members of the Royal Family."

[A telegram expressing the heartfelt thankfulness of the Members at His Majesty's rapid recovery was sent to the King after the Dinner, and a reply was received the next morning from Lord

Knollys, as follows:—"Cowes, 11.25 A.M. The King thanks you and the Members of the Institution of Mechanical Engineers for your kind telegram."]

The PRESIDENT then proposed the toast of "The City of Newcastle, and Trade on the Tyne," and remarked that they were particularly pleased to meet in Newcastle, because it was one of the principal centres of mechanical engineering in the kingdom. It owed the high position it now held to the work of the engineer, and he did not think they need be at all surprised at the results attained when they remembered the names of the brilliant men associated with Newcastle. Referring to the Trade on the Tyne the President stated that the Tyne and district produced over half the ship-tonnage and over two-fifths of the marine-engine horse-power turned out last year in the United Kingdom. It must also be remembered that shipyards and ordnance works, such as those existing in the district they were visiting, would, in time of war, become so many auxiliary dockyards and arsenals, the value of which to the nation would be incalculable. As regarded the Elswick Works which they had visited that afternoon, everyone who took part in the visit of 1881 must have been struck by the enormous strides which had been made since that date; but these improvements were characteristic of the spirit of advancement and enterprise to be seen everywhere on Tyneside. The toast was acknowledged by the Right Worshipful the MAYOR OF NEWCASTLE, who alluded to the system of electric tramways recently established in the city, which was not surpassed in any town in the kingdom.

The toast of "The Reception Committees" was proposed by Mr. J. HARTLEY WICKSTEED, Vice-President, who gave some interesting reminiscences of previous Meetings in Newcastle. It was responded to by Mr. H. I. BRACKENBURY, Mr. H. H. WAKE, and Mr. J. R. FOTHERGILL.

Professor R. L. WEIGHTON then proposed the toast of "The Institution of Mechanical Engineers," remarking that the establishment of the Institution might be regarded as contemporary with the progress of engineering science, and in this progress Newcastle was peculiarly concerned, for amongst the Past-Presidents

of the Institution—men pre-eminent for putting the science of engineering into practical effect—were George Stephenson, Robert Stephenson, Lord Armstrong, Sir Lowthian Bell, Mr. Westmacott, and Sir William White. The President, in responding, gave some interesting statistics showing the growth of the Institution since it first met in Newcastle in 1858, with a membership of 301, and a balance at the bank of £407, until the present day, when it had 3,491 members and invested funds of £41,751. He also referred particularly to the fact that, whereas in their Annual Report immediately preceding their last visit to Newcastle in 1881, the Council especially congratulated the Members on an increase of membership of 32 during the previous year, they had in their last Report—that for 1901—to record an increase in the number of members of all classes amounting to 326. The progress indicated by these figures showed, he thought, that the Institution was yet very far from having attained its full maturity in influence and activity.

On Wednesday Afternoon, 30th July, after luncheon in the Old Assembly Room, by invitation of the Local Committee, two alternative visits were made.

One was down the River Tyne in the steamer "J. C. Stevenson," by invitation of the Tyne Improvement Commissioners, when the following Works were visited:—Messrs. Palmer and Co.'s Works at Jarrow; Coal Staithes and Electro-Pneumatic Signals of the North Eastern Railway Co.; Tyne Commissioners' Coal Staithes, under the guidance of Mr. C. B. Goldson, chief assistant engineer; Messrs. Smith's Dock Co.'s Pontoon Docks; and the Tyne North Pier Reconstruction Works at Tynemouth, under the guidance of Mr. Ivan C. Barling, resident engineer.

The alternative visit was made to the following Works at Walker and Wallsend: Messrs. C. S. Swan and Hunter; the Wallsend Slipway and Engineering Co.; the North Eastern Marine Engineering Co.

The following Works were also open to the visits of Members :—

Consett Iron and Steel Works, Consett.

Newcastle-upon-Tyne Electric Supply Co.'s Power House, Neptune Bank; Sub-Stations, and Shipyard Installations, Wallsend.

Newcastle Tramway Power Station, Manors.

Wigham-Richardson and Co., Neptune Works, Walker.

In the evening a Conversazione—to which Ladies were also invited—was held at Jesmond Dene House, by Sir Andrew and Lady Noble.

On THURSDAY, 31st July, three alternative Excursions were made.

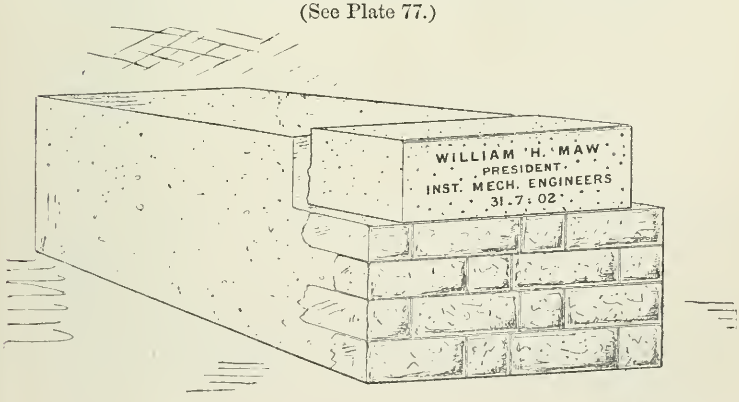
One was by special train to Sunderland, where the Members were received in the Town Hall by the Deputy Mayor, Alderman Stansfield Richardson, J.P. The Harbour Works at Roker were then visited, by special electric trams, when the President laid a granite stone bearing a suitable inscription commemorating the visit of the Institution. This stone, shown on the opposite page, together with the concrete block on which it rested, was next taken on a trolley to the end of the Pier, where it was placed in position by the President, Plate 77. After luncheon in a marquee at the Harbour Works, at the invitation of the River Wear Commissioners, the Members proceeded up the River Wear in steamers, provided by the Commissioners, to visit the various shipyards and engine works on the river. In the evening they were entertained at dinner in a

marquee at the Harbour Works, by invitation of the Sunderland Local Committee, the Deputy Mayor being in the chair. After dinner, they proceeded to the Pier, which had been illuminated and decorated for the occasion. The return journey was made by special train.

Another Excursion was made to Newburn, to visit the Works of Messrs. John Spencer and Sons. After luncheon in the Workmen's Institute, by invitation of Messrs. John Spencer and Sons, the Members visited the firm's Newburn Steel Works.

A third Excursion was made by special train to the Rede Valley Reservoir of the Newcastle and Gateshead Water Co. On arrival at Woodburn, the journey was continued by a Light Railway to Catcleugh, passing en route the village of Otterburn, Percy Cross, and the Battlefield of Otterburn. After luncheon at Catcleugh, by invitation of the directors of the Newcastle and Gateshead Water Co., the Rede Valley reservoir was visited. The return journey was made by the Light Railway to Woodburn, and thence by special train to Newcastle.

Granite Stone set in 45-ton Concrete Block, at the end of Roker Pier.
(See Plate 77.)



On Friday, 1st August, four alternative Excursions were made.

One was by train to the Hartlepools. After luncheon in the Grand Hotel, West Hartlepool, by invitation of the Local Committee, various Shipbuilding Yards and Engine Works were visited, under the guidance of members of the Local Committee.

Another Excursion was made to Bamburgh Castle, by special train to Belford, and thence by brakes. Members and Ladies were entertained at luncheon in the King's Hall, by invitation of W. A. Watson-Armstrong, Esq. The return journey was made by special train.

A third Excursion was made to Chillingham Castle, by special train to Belford, and thence by brakes. After visiting the Grounds and viewing the wild cattle belonging to the Earl of Tankerville, the Members and Ladies were entertained at luncheon, by invitation of Sir Andrew and Lady Noble. The return journey was made by special train.

A fourth Excursion was made by special train to Rothbury, where the Members and Ladies were entertained at luncheon at Cragside by W. A. Watson-Armstrong, Esq. The return journey was made by special train.

CORPORATION TRAMWAY POWER-HOUSE, MANORS, NEWCASTLE-UPON-TYNE.

The Power Station for the system is located almost in the centre of the area to be supplied, and consists of large steel-framed buildings, with brick walls. A connection from the railway runs in at a high level over a timber and steel elevated road, and the coal discharges direct from the hopper railway wagons into the bunkers above the boilers, from which it is fed by automatic weighing machines into automatic stokers. For steam-raising purposes there are eight Lancashire boilers, each 30 feet long by 8 feet 6 inches diameter, steam pressure 160 lbs., with economiser and natural draught, the chimney being of brick 177 feet high. The ashes are discharged by gravity into barrows or trucks beneath the boiler-house.

In the engine-house there are three marine-type engines, fitted with Corliss valves, two of 1,000 H.P. each, built by Messrs. Victor Coates and Co., of Belfast, and one of 2,000 H.P. built by the Wallsend Slipway and Engineering Co. The engines are provided with surface condensers and Edwards air-pumps. Three dynamos, built by the British Westinghouse Co., are coupled direct to the three engines, and supply current at 500 volts through a large switchboard to the traction mains. There is a complete system of oil-lubricating pipes with supply tanks in the roof, and three "Cruse" steam superheaters have been fixed. A 50-ton 3-motor electrical crane runs the whole length of the engine-house. A battery of boosters will shortly be installed. In addition, current is supplied from the same switchboard by separate feeders for the arc lighting of the town.

The arrangement of surface condensers is dealt with in a Paper by the consulting engineer, Mr. Charles Hopkinson (page 437). The circulating water is pumped from 90 feet below the level of the

engines, two large 24-inch mains running down to a pumping station alongside the Quay wall.

There are at present $16\frac{1}{2}$ miles of double track in use, and about 165 cars of various types, bogie and 4-wheeled, for which there is one car-shed in the centre of the town, another at the extreme north end at Gosforth, and the third is at the east end at Byker. The latter forms also a machine shop for repairs and building of cars. The general manager is Mr. A. E. Le Rossignol.

SIR W. G. ARMSTRONG, WHITWORTH AND CO., ELSWICK WORKS, NEWCASTLE-UPON-TYNE.

(*See pages* 586 *and* 587.)

The engine works were started in 1847 for the purpose of exploiting Lord Armstrong's inventions for hydraulic machinery. The first gun (a 3-pounder) was manufactured in July 1855, and is still shown to visitors to Elswick. The Elswick Ordnance Co. was formed in 1859. In 1882 Mr. Mitchell's shipyard at Walker joined the Elswick Works, and in 1883 the Elswick Shipyard was established. In 1882 the private firm came to an end, and a company was started in the name of Sir W. G. Armstrong, Mitchell and Co. This title was altered in 1897, in consequence of the amalgamation with the Openshaw Works of Sir Joseph Whitworth and Co.

The Steel Works were opened in 1883. This department was started with the idea of supplying gun steel to the Ordnance Works, but of late years large quantities of outside orders have been undertaken. In 1885 a branch was started entirely for Italian orders at Pozzuoli, on the Bay of Naples.

A few figures will give an idea of the growth of these enormous works. In 1847 the pioneers of Elswick bought a piece of ground of $5\frac{1}{2}$ acres. The company now possesses 230 acres. The first Elswick pay-sheet amounted to £9 17*s.* 10*d.* for a fortnight. A recent pay-sheet shows nearly £40,000 paid in a single week to the workmen, who number about 28,000. The consumption of coal in a year is about 200,000 tons, with 36,000 tons of coke.

Steel Works.—At the east end of the Elswick Works are the steel works, the entrance to which is in Water Street. These works extend over a length of 1,100 feet, and cover an area of about 50,000 square yards. The melting plant comprises eight furnaces, which are capable of turning out weekly upwards of 1,200 tons of steel, and ingots can be cast up to a weight of 80 tons. The forging plant is worked hydraulically, and can turn out 120 tons of forgings per week. There are four large forging presses and several smaller ones. The largest of the presses exerts a pressure of 5,000 tons.

In the Foundry, steel castings for gun and carriage work, marine and electrical general machinery and anchors are manufactured, and the largest stem and stern posts and rudder frames can be dealt with. The weekly output of castings amounts to about 60 tons. The pressure required by the forging plant is supplied by five pairs of Corliss pumping engines, each indicating 1,000 H.P. Propeller shafting has been forged under the forging presses in lengths of 80 feet, which shafting has afterwards been trepanned from end to end. There is an extensive plant of heavy machinery for dealing with the forgings and castings. The department employs about 2,000 hands.

The shops in the ordnance department will be taken in the following order:—No. 18 Shop.—Finishing and finished guns, 12 inches calibre and less. Shields in various stages of manufacture, and the process of winding wire in the construction of guns.

No. 29 Shop.—General gun carriage and electric shop. The 9·2-inch garrison mountings will be especially noticeable.

No. 33 Shop.—Slides for 12-inch mountings.

No. 39 Shop.—Electric shop, Elswick pattern dynamos and engines. These two shops were built on the site of the old shop, which was destroyed by fire in June, 1899.

No. 11 Shop.—Machine shop for guns, turning, boring, and rifling machines.

The following shops in the engine works are then visited:—Brass rolling mills, north erecting shop, south erecting shop, and bridge yard.

REFERENCE TO PLAN OF ELSWICK WORKS.

DESCRIPTION OF SHOPS.

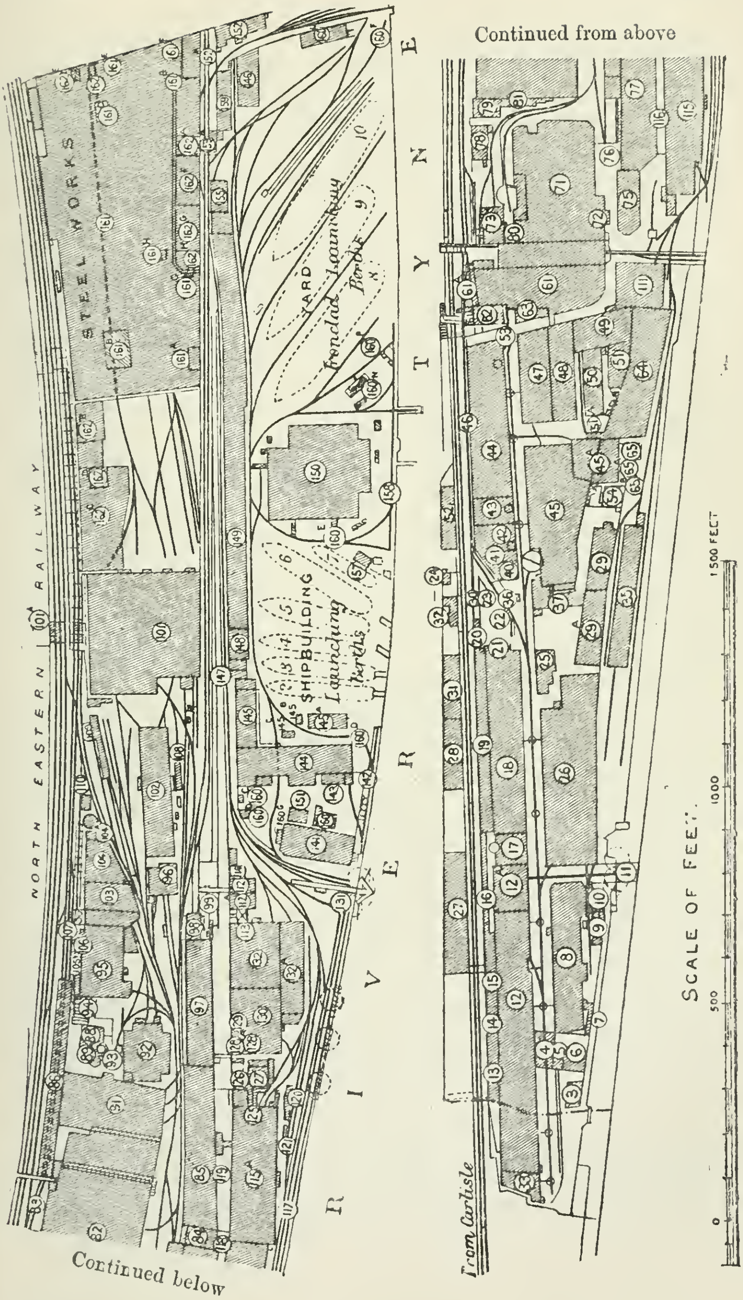
3. Foreman's House.
4. Pipe Shop and Test.
5. General Store.
6. Fitting Shop.
7. Millwrights' Tool Store.
8. Erecting Shop (South).
9. Joiners' Shop.
10. Coal Store.
11. Jetty (West).
12. Erecting Shop (North).
12a. Fitting and Brass Finishers' Shop.
13., 14., 15., 16. Rolling Plant, &c.
17. Engine and Boiler House and Plan Store.
18. Crane and Bridge Erecting Shop.
19. New Smiths' Shop, Iron and Chain Store and Test.
20. Painters' Shop and Store.
21. Coach House and Plan Room over.
22. Iron Store.
23. Fireproof Paint and Oil Stores.
24. Office Lodge.
25. Offices (Old).
26. Bridge Yard.
27. Pattern Shop and Time Office.
28. Pattern Sheds.
29. New Offices.
29a. New Offices (Extension Westward).
30. Hauling Engine House and Coal Bunkers.
31. Pattern Store and Dining Room.
32. New Stables and Coach House.
33. New Brass Foundry.
35. Gun Carriage Shop (No. 38).
36. Gateman's Lodge.
37. Offices (Ordnance).
40. Boiler House.
41. Engine House.
42. Machine Shop (No. 1).
43. Brass Finishing Shop (No. 3).
44. Forge Shop (No. 4).
45. Gun Machine Shop (No. 11).
45a. do.
46. Railway and Coal Depôts.
47. Gun Machine Shop (No. 2).
48. Gun Machine Shop (No. 26 and No. 12) over
49. Gun Machine Shop (No. 14).
50. Polishing Shop (No. 10 and Store No. 13).
51. Fuze Shop.
51a. Packing Box Shop.
52. New Inspectors' Offices.
53. Time Office.
54. New Test House.
61. Gun Carriage Shop (Nos. 28 A, B, C and D).
61a. Gun Carriage Shop Extension.
61b. Time Office.
62. Boiler House.
63. Engine House.
64. Gun Carriage Shop (No. 17).
65. Boiler House.
65a. Engine House.
65b. Accumulator House.
71. Foundry.
72. Time Office.
73. Machine Shop E and F (28).
75. Electric Shop (39).
76. Shell Furnace House.
77. Machine and Cart Case Shop (33).
78. Boiler House.
79. Millwrights' Shop (No. 30).
80. Foundry Pattern Store, &c.
81. Engine House.
82. Gun Carriage Shop (No. 29).
83. Time Office.
84. Shell Coating Shop, &c. (No. 34).
85. Smiths' Shop Extension (No. 35).
86. Blast Furnace Depôts.
88. Engine House (Blast Furnaces).
89. Accumulator House and Engine.
91. New Store.
92. Steam Hammer Shop (No. 31).
93. Furnaces.
94. Boiler House.
95. Coiling Shop (No. 32).
96. Rifling and Grinding Shed.
97. Smiths' Shop (No. 35).
98. Coal Shed and Store.
99. Store.
101. Machine Shop (No. 18).
101a. Time Office under Bridge.
102. Machine Shop (No. 5).
103. Forge (No. 8).
104. Shell Shop (No. 9).
104a. Lead Casting Shop.
105. Accumulator House.
106. Engine House.
107. Engine House.
108. Wagon Repairing Shop.
109. Locomotive Shed (Large).
110. Locomotive Shed (Small).
111. Turret and Machine Shop (No. 16).
112. Engine House.
112a. Boiler House.
113. Accumulator House.
114. Coppersmiths' Shop (East of No. 112).
115. Gun Machine Shop (West No. 6).
115a. Gun Machine Shop (East No. 7).
116. Gas Engine House.
117. Iron Ore Jetty (end to end).
118. Gas Engine House.
119. do.
120. Store (No. 21 Shop).
121. Stevedore's House.
125. Accumulator House.
126. Engine House.
127. Boiler House.
128. Time Office and Machinery Store.
128a. Pumping Engine House.
129. Millwrights' Shop (No. 24).
130. Two Wooden Sheds (No. 24).
131. 120-Ton Crane Jetty.
132. Turret and Machine Shop (No. 24).
132a. Extension to No. 21 Shop.

Shipyard.

141. Blacksmiths' Shop.
142. Jetty.
143. Boiler House and Brass Store.
144. Stores and Modelling Room.
145. Offices.
145a. Shed for laying down Ironwork.
145b. Fire Brigade House.
145c. Lavatory and W.C.'s.
146. Bulkhead Shop.
147. Inspectors' Offices.
148. Coppersmiths' Shop.
149. Tool Shop and Machine Shop.
150. Plate Shop.
151. Mahogany Drying Shed and Store.
152. Workmen's Dining Hall.
152a. Gateman's Cabin.
155. Locomotive Shed, Millwrights' and Electricians.
157. Oakum and Pitch House.
158. Jetty (East No. 2).
159. Riggers' Spar Shed.
159a. Lodge and Time Office.
160. Electro Zincing and Ship's Stores.
160c. Water Meter House.
160d. Store.
160e. Stock Taker's Cabin.
160f. Jetty (East).
160g. Weigh House.
160l. Mast Making Shop.
160n. New Paint Shop.
160o. Corrugated Iron Shed.
160p. Store (Riggers).

Steel Works.

161. Main Building of Steel Works.
161a. Test House.
161b. Middle Level Pumping Engine House.
161c. Accumulator House.
161d. Store Hoist, &c.
161e. Gas Engine House.
161f. Engine House.
161g. Accumulator House.
161h. Engine House.
162. Offices of Steel Works.
162a. Paint Store, &c.
162b. Joiners' Shop and Boiler House, &c.
162c. Extension to Steel Works (47).
162d. Bessemer Engine House.
162e. Store and Dining Rooms.
162f. Low Level Engine House.
162g. Boiler House.
162h. Engine House.



Sir W. G. Armstrong, Whitworth and Co.'s Elswick Works, Newcastle-upon-Tyne.

Ordnance Department.—No. 16 and 17 Shops.—Machinery for the manufacture of gun carriages of all descriptions.

No. 6 Shop.—Machinery for the manufacture of all the larger sizes of guns. The double-headed lathe on the right as the shop is entered is long enough to allow two 9·2-inch guns to be turned simultaneously.

No. 7 Shop.—Erecting shop for 12-inch mountings for H.M. ships of the "Duncan" class. These mountings are intended to carry a pair of 12-inch 50-ton guns, which throw a shot of 850 lbs. weight with a velocity of 2,481 feet per second, and are the most powerful type of gun at present being supplied to the British Navy. The guns are placed in cradles, which move upon pivoted slides. These slides are provided with the necessary gear for working the guns and for absorbing the energy of the recoil. The recoiling energy of the gun is about 500 foot-tons. The mountings and all the gear for working them are carried in an armoured turret made to revolve upon live rollers by a powerful hydraulic turning engine. The total revolving weight is about 400 tons, and the speed of revolution anything from a maximum of one revolution per minute down to a dead creep.

The service of the ammunition is very rapid. It is brought up through a central trunk to the lower storey of the turntable, called the working chamber, by means of suitable cages. From these cages it is transferred to the loading cages, which transport it to the rear of the guns immediately the guns are in a position to receive it. It is then rammed home by a chain rammer. Each gun is trained and elevated by a single lever capable of performing either operation at will, or both simultaneously. The whole of the machinery, both in the turret and in the shell room, is worked by hydraulic power supplied at a pressure of 1,000 lbs. per square inch by a steam pumping-engine of about 370 H.P. A speed of two rounds per minute per gun has been obtained from one of these turrets.

Shops Nos. 6 and 7 were rebuilt after the fire in June 1899.

Shipyard.—Shops for performing all machining operations necessary for the building of ships will be seen here.

The following will be seen in this department:—

On the Berths.—Keel of third-class cruiser of about 4,000 tons displacement. Cable repairing steamer nearly ready to be launched. The next berth is being prepared for the construction of a third-class cruiser of 3,000 tons displacement. Also a first-class battleship of about 12,000 tons displacement. The next berth is in course of preparation for the construction of a first-class armoured cruiser of nearly 11,000 tons displacement. Further on, occupying single berths, are two vessels, which are called coal haulabouts, building for H.M. coaling service, and both almost ready for launching.

Alongside the shipyard, in the water, is H.M. first-class cruiser "Lancaster," of nearly 10,000 tons displacement. A large steel screw tank-steamer, capable of carrying about 7,000 tons of liquid fuel, is almost complete and on the point of sailing.

CONSETT IRON WORKS, BLACKHILL, CO. DURHAM.

Coal and Coke.

Collieries.—The Consett Iron Co. at the present time owns eleven collieries, extending over an area of 13,000 acres, and producing annually about one and a half million tons of coal.

The number of coke ovens owned is about 1,050, and the annual production of coke therefrom about 600,000 tons. A larger portion of this is consumed at the company's blast-furnaces, and the remainder is disposed of for use in the furnaces, &c., of Cumberland, Cleveland, and foreign pig-iron producing centres.

Pig-Iron.

Blast Furnaces.—These, seven in number, are each 55 feet high, and 9 feet diameter of hearth; height to top of boshes, 20 feet; diameter of bosh, 20 feet; diameter of throat, 14 feet 6 inches; and

bell with 10 feet 6 inches opening. There are seven tuyères to each furnace. All the furnaces are fed with material by means of bell and hopper, with standard beam and hydraulic brake. The ore and other material for the furnaces is brought in on a high-level approach, considerably above the tops of the furnaces, in bottom door trucks, and from these is tipped into depôts from which the charging barrows are filled.

All the furnaces are served with three Cowper stoves each, varying from 65 to 90 feet in height, and from 21 to 24 feet in diameter. The pressure of blast now maintained is 5 lbs. per square inch, and its temperature on entering the furnace is about 1,200° F. At the present time six furnaces are in blast, the seventh one is being relined. All the six furnaces are making Bessemer pig from imported Spanish and other ores, and produce on an average 750 tons per furnace per week. The limestone used comes from the company's own quarries at Stanhope in the Wear Valley.

The blowing engines are of two kinds, the beam and the vertical tandem type.

There are six beam engines, two being obsolete which are shortly to be removed. The remaining four of this class have steam cylinders 4 feet 2 inches diameter, blowing cylinders 8 feet 4 inches diameter, and 9 feet stroke, designed for a blast pressure of 5 lbs. per square inch, and were made by the Lilleshall Iron Co. The two vertical tandem engines have steam cylinders 4 feet 2 inches diameter, blowing cylinders 8 feet 4 inches diameter, and 5 feet stroke, designed for a working pressure of 10 lbs., and in case of emergency will work to 15 lbs. per square inch. They are fitted with the Wheelock steam valve-gear and Adamson's expansion governor. These engines were built and recently erected by Messrs. D. Adamson and Co., of Dukinfield, near Manchester.

The steam required for driving the blast engines, &c., is raised by nineteen double egg-ended boilers, each consisting of two lengths 35 feet long by 4 feet 6 inches diameter, and twelve double tubular boilers, each 31 feet 4 inches long, six of which are 7 feet diameter, and the remainder 7 feet 6 inches diameter. At the present time three blocks of two boilers are being erected, each of

the Babcock and Wilcox water-tube type, capable of working to a pressure of 160 lbs. per square inch. The waste gases from stoves and boilers pass through a large underground flue to a fire-brick chimney, 250 feet high and 16 feet 6 inches diameter inside at the top. The slag from the furnaces is removed in side-tipping ladles of 10 tons capacity.

In Nos. 1 and 4 blowing-engine houses are placed engines and brush dymamos, which generate the energy for lighting the works.

Steel Plates.

The Melting Shops supplying ingots for the manufacture of steel plates are two, designated respectively East and West. In the East Shop is a range of nine Siemens open-hearth furnaces, six of them being of 35 tons capacity, and three of 28 tons. In the West Shop there are eleven similar furnaces, but nine of them are only of 20 tons capacity, one is 28 and one 35 tons. These furnaces are supplied with gas from a range of 33 steam-blown Siemens producers. The two melting shops produce about 4,200 tons of ingots per week.

No. 2 *Cogging Mill.*—A 28-inch Cogging Mill is driven from the No. 2 Plate Mill Engine, through steel bevel gearing, and is reversed by steam clutch. The mill consists of one stand each of pinions and rolls fitted with the usual live roller frames, screwing and edging gear. The cutting is done by a steam-hammer placed at right angles to the mill and served by a steam jib-crane. This mill is capable of dealing with about 1,650 tons of ingots per week.

No. 1 *Plate Mill.*—This has one stand of pinions, one stand of roughing, and one stand of finishing rolls, each 6 feet 3 inches by 25 inches, driven by a high-pressure, direct-acting, non-condensing fly-wheel engine, the fly-wheel weighing 70 tons. A steam lift is provided whereby slabs weighing from 20 to 25 cwts. may be dealt with. The capacity of the mill for production of plates is equal to 400 tons per week.

No. 2 Plate Mill is a clutch reverse mill and contains one stand of pinions, one stand of roughing, and one stand of finishing rolls, each 7 feet by 25 inches. The mill is driven by a high-pressure, direct-acting, non-condensing fly-wheel engine; and the reverse action is obtained by the five-wheel method and clutch motion. All the wheels, shafts, and clutches are made of Siemens steel. Each of the above mills has conveniently placed for its use plate and scrap shearing machines.

There are six Lancashire, two Babcock and Wilcox boilers, and fifteen furnace stack boilers, making a total of twenty-five boilers for these mills. The output of No. 2 mill is about 800 tons of plates per week.

No. 4 Cogging Mill is a 45-inch mill, having one stand of pinions and one stand of cogging rolls, driven by a pair of coupled high-pressure, non-condensing, direct-acting engines, geared at 2½ to 1, the wheels, shafts and couplings all being of Siemens mild steel. The mill is provided with live roller gear on each side, and hydraulic edging gear on the delivery side. The top roll is balanced by hydraulic, and screwing is done by steam power. In a line with the mill is placed a large bloom shearing machine, driven by high-pressure reversing engines, and provided with live rollers mounted in falling tables to the receiving and delivery sides of the shear. The ingots are heated in six vertical heating furnaces served by a steam derrick locomotive crane. This plant is capable of cogging 2,600 tons of steel ingots per week.

No. 3 Plate Mill has one stand of pinions, one stand of roughing, one stand of finishing, and one stand of chequering rolls, the roughing and finishing rolls being each 6 feet 3 inches by 25 inches, and the chequering rolls 5 feet 6 inches by 25 inches, and all being driven by a high-pressure, direct-acting, non-condensing fly-wheel engine, geared inversely as 1½ to 1. The mill has a similar steam lift to that in No. 1, and it is also equipped with the necessary plate and scrap cutting shears. It produces about 380 tons of plates per week.

No. 4 Plate Mill.—This is a 28-inch clutch reverse mill, and is also driven by a high-pressure, direct-acting, non-condensing fly-wheel engine, the reverse action being obtained by the five-wheel method and clutch motion, and all gearing and shafts being made of Siemens mild steel. The mill has one stand of pinions, one stand of roughing, and one stand of finishing rolls, these latter being 8 feet by 28 inches. On the delivery side of the mill is provided a traversing steam platform, constructed so as to work the plates to and fro through the rolls, and also to take them bodily from the roughing to the finishing rolls. On the receiving side are also fixed live roller frames. Overhead for roll changing is a 15-ton steam travelling-crane running upon steel-built box girders. Two strong plate shearing machines are provided, each capable of cutting $1\frac{1}{2}$ inch plates. The output of this mill is 1,250 tons of steel plates per week. A battery of fourteen hand-fired Lancashire boilers is installed outside the roof area; and in addition there are in the cogging and plate mills sixteen boilers, making a total of thirty; eight of these latter being vertical, four Lancashire and four Cornish furnace boilers.

ANGLES, &c.

Melting Furnaces.—The ingots for the Angle Mills are supplied from the North Melting Shop which adjoins them, and which contains seven Siemens open-hearth furnaces, the charges for which are 28 tons. These furnaces are of similar construction to those in the East and West Shops, but laid out somewhat more conveniently with ample space, and having unusually large and well ventilated valve chamber.

Fifteen blocks of Siemens producers supply the gas for the melting furnaces, and these also are conveniently laid out for dealing with both coal and ashes. The ingot producing capacity of these furnaces is 1,800 tons per week.

Cogging Mill.—The 45-inch cogging mill is driven by a pair of geared high-pressure non-condensing engines, cylinders 45 inches diameter by 5 feet stroke, geared at 2 to 1, fitted with piston-valves

and Allan's link motion, and comprises one stand of roll housings, and one stand of pinions, seated upon cast-iron bed-plates. The mill, with live roller gear on each side, is designed for dealing with slabs or billets. The capacity of this mill is about 2,500 tons per week.

Angle Mills.—The 32-inch angle mill is driven by a pair of reversing high-pressure non-condensing engines, with cylinders 54 inches diameter by 4 feet 6 inches stroke, coupled direct to the mill by an inside crank-shaft and steel couplings fitted with piston-valves and Allan's link motion. The mill, which is about 125 feet distant from the bloom shear, has one stand of pinions, one stand of roughing, and one stand of finishing rolls, all coupled through steel boxes and spindles. The capacity of this mill is about 2,000 tons per week. The 22-inch angle mill is also driven by a pair of reversing high-pressure non-condensing engines, with cylinders 40 inches diameter by 4 feet stroke, coupled through steel boxes and spindles in the same manner as the 32-inch mill. It comprises one stand of pinions, one stand of roughing, and one stand of finishing rolls, with live roller gear on the receiving and delivery sides, and an inclined shoot on the receiving side only. The live roller gear leads from the mill to the billet shear and steam circular sawing machine, and on a line with these is a relief live roller frame for distributing the rolled bars, as in the 32-inch mill. The capacity of this mill is about 1,600 tons per week.

The 12-inch guide-mill is driven by a high-pressure non-condensing fly-wheel engine, with cylinders 30 inches diameter by 2 feet 6 inches stroke, fitted with piston valve and governor gear, and consists of one stand of pinions, one stand of roughings, one stand of finishing, and two stands of guide rolls, all coupled through steel boxes and spindles. A steam circular sawing machine and billet shear are likewise provided. This is a reheating mill, and two furnaces are conveniently placed, with stack boilers attached. The capacity of this mill is about 350 tons per week.

Overhead Cranes.—The cogging mill is served by a 25-ton overhead square shaft steam-crane, and two overhead cranes, each of 15 tons capacity, with boiler attached, traverse the three angle mills and roll turning shop, these being all in one line and under one roof.

Roll Shop.—This is placed at the end of the 32-inch mill, and contains three powerful lathes, each driven by its own engine.

Hydraulic Plant.—Two sets of Worthington high-pressure pumps, one accumulator and tank, with automatic governor gear attached, are provided, working to a pressure of 700 lbs. per square inch.

Boilers.—There is a battery of eighteen Lancashire boilers fired by automatic stoking gear. They are arranged in pairs, and work through nine iron chimneys lined with brick. The mill furnace-boilers are of the vertical type, with one internal flue fitted with cross tubes, and stand upon cast-iron columns. All the boilers are designed to carry 100 lbs. per square inch, and in daily working are pressed to 80 lbs. The steam-pipes from 9 inches diameter upwards are made from Siemens mild wrought steel in lengths up to 16 feet, welded from end to end, with solid flanges contracted and riveted on.

The bar bank is arranged at the south end of the mills. Bar skidding gear is provided, worked from the driving engine through shafting, and the friction cones being set in motion by hydraulic rams. The loading on the bank is done by two 3-ton steam locomotive travelling cranes, having 30 feet jibs.

Various.—In connection with the works are the usual engineering shops, namely, fitting, blacksmith, boilersmith, pattern-maker, joiner, and other shops, where renewals and repairs to machinery and other plant are executed.

The foundry is situated at Crookhall, about one and three-quarter miles from the main works, and has a capacity of 200 tons of castings per week. The plant consists of three cupolas, air furnace,

drying stoves, loam mill, and necessary blowing plant, with two 25-ton overhead steam cranes, and one hand-power jib crane. The ingot moulds, and the whole of the castings necessary for mill and general ironwork repairs, are made here. Connected with the place are pattern and blacksmiths' shops, and a brass foundry.

The brick works are south-east of and about half-a-mile from the iron and steel works, and have a capacity of about 120,000 bricks per week. There are ten brick-burning kilns, each equal to 18,000 bricks per charge, fired by the waste heat from four rows of coke ovens immediately adjoining, the waste gases from which are collected in one large flue, and, after passing through the kilns, are conveyed in small flues under the floor of the drying shed. There are also a small mill and press for mixing and making ganister bricks, which are burnt in two suitable hand-fired kilns.

The locomotives and locomotive cranes are for convenience divided into classes, the locomotives into A and B, and the locomotive cranes into D and E, the entire number of both in use being fifty-five. The locomotive repairing shop is situated at Templetown, about a mile from the works, on the main line between the works and the collieries, and is furnished with all necessary tools and appliances.

MESSRS. R. AND W. HAWTHORN, LESLIE AND CO., ST. PETER'S AND HEBBURN, NEWCASTLE-UPON-TYNE.

This company was formed in 1885, by a combination of the engineering works of Messrs. R. and W. Hawthorn and the shipbuilding and graving dock business of Messrs. Andrew Leslie and Co. On the death of Mr. R. Hawthorn in 1870, the chief management devolved on Mr. F. C. Marshall, who for some years was on the Council of this Institution. Foreseeing a great future for marine engineering, he took a large site at St. Peter's at the east end of Newcastle, where there was room to build a deep-water quay, and there the marine-engine business has grown to its present size.

The shipyard was commenced by Mr. Leslie in 1853 on a small scale, and by 1870 it occupied a high position, both as regards the number of ships and class of work turned out. Nearly all the vessels of the Russian Volunteer Fleet have been built in this yard, and a total of no less than 380 ships have been launched there. Among these may be mentioned "merchant tramps," oil tank-steamers, vessels for the Australian and New Zealand chilled meat trade, torpedo-boat destroyers for the British Government, the "Calais-Douvres"—a double-hulled steamer built for the Channel passage—several yachts, Atlantic liners, &c. The yard is thoroughly equipped with the latest appliances, which are driven electrically. Some large orders have been executed for the repair of ships. In 1871 they lengthened by 50 feet five vessels of the Compagnie Générale Transatlantique. Originally these vessels were 350 feet long, and were fitted with paddle machinery. The latter was removed, the vessels cut in two, lengthened, and a duplicate set of screw machinery installed. The most recent notable steamship to be repaired is the "Denton Grange," 420 feet long by 54 feet beam and about 9,000 tons deadweight, which went ashore at Las Palmas when bound for the Cape with troops. An important feature of the repair is the supporting of the huge mass while the cutting away and re-instating of the double bottom is in progress.

The engineering department of these works was established in 1817 by Robert and William Hawthorn, who themselves worked and were assisted by a few millwrights. Although a great amount of attention was devoted to the construction of large pumping machinery for local collieries and waterworks, they were among the first to build locomotives for our great railway companies. At the present this branch of the business is chiefly occupied with locomotives for Colonial railways, and tank engines for collieries, &c. In addition they have built a large number of locomotive cranes. As regards the marine-engine branch of the works, the output in 1898 was no less than 76,500 I.H.P. In 1872 they supplied engines of 2,100 H.P. to the Peninsular and Oriental Steamship Co.'s liners "Khiva" and "Kashgar," which at that time was considered very large power. A large amount of work has been

2 T

done for the British Navy; since 1890 they have completed machinery for no less than 29 of H.M. ships, which includes vessels of every type, from the torpedo-boat destroyer to the first-class battleship; and during the past few years this company has built various kinds of water-tube boilers, more especially those of the Belleville type for the large vessels, and of the Yarrow and Thornycroft for the small vessels. Experiments are being made with a modified boiler of the Thornycroft-Marshall type. The number of men and boys employed is about 5,000.

NEWCASTLE AND DISTRICT ELECTRIC LIGHTING CO.'S WORKS.

The works of this company are situated in Forth Banks and The Close. Operations were commenced and electrical energy supplied in 1889. The station was equipped with three Lancashire boilers and four 75-kilowatt Parsons turbo generators. The present capacity of the works is 3,000 kilowatts, including two 400-kilowatt continuous-current generators.

The Close Works are new and in course of being fitted out. The first installation will consist of two 1,000-kilowatt turbo generators.

A description of the above works is given in a Paper by the Company's Engineer, Mr. W. D. Hunter, at the present Meeting (page 441).

NEWCASTLE-UPON-TYNE ELECTRIC-POWER SUPPLY CO.'S WORKS, NEPTUNE BANK.

General Notes.—In June 1899, the Walker and Wallsend Union Gas Co. obtained Parliamentary powers to supply the urban districts of Wallsend and Willington with electric power, and proceeded, in

January of the following year, with the erection of a power-station on a site midway between Carville and Walker, close to the riverside branch of the North Eastern Railway, to the designs of Mr. C. H. Merz. In October 1900, the Newcastle-upon-Tyne Electric Supply Co. purchased the entire plant put down by the Gas Co., with the exception of the cables and sub-station machinery installed for the purpose of supplying the works in the area in which the Gas Co. had obtained Parliamentary powers. The Supply Co. further entered into an agreement with the Gas Co., in which the latter undertook to buy electricity in bulk from the former. The Supply Co. also obtained powers authorising them to lay high-tension cables from their power-house at Wallsend to various sub-stations in Newcastle. At the same time they decided to change their entire system of supply, which, up to this date, had been by means of single-phase alternating current, generated at Pandon Dene Power-Station, at a pressure of 2,000 volts, with house-to-house transformers. The new scheme, for which Mr. C. H. Merz has acted as Consulting Engineer, included the generation of three-phase current at 5,500 volts, having a periodicity of 40 cycles per second, and the transformation of the same to continuous current by means of motor generators in sub-stations designed to have a total capacity of 2,000 kilowatts each. In the beginning of 1901 the work of changing the lighting network from alternating to direct current was started, the direct current being on the three-wire system (2×240 volts). It may be of interest to note that since the Neptune Bank Power-Station started work, motors having an aggregate capacity of over 4,000 H.P. have been connected up. These motors are used in all classes of trades, and vary in size from $\frac{1}{2}$ H.P. to 50 H.P. This company's scheme was the first of the large power schemes to be started in this country.

Description of Power Station.—The Power-House was constructed in accordance with the plans of Messrs. Sandeman and Moncrieff, of Newcastle. The boiler-house, which is of corrugated iron, adjoins the engine-room on the south side. Both these buildings were designed so that extensions could be easily effected. The dimensions

of each building are 160 feet by 32 feet. On the north east of the power-house lies the cooling pond, where the circulating water is cooled by means of Körting Brothers' spray nozzles, capable of cooling 325,000 lbs. of water per hour. This system of dealing with the circulating water was adopted because of the great cost of pumping sufficient water direct from the river, which is about 60 feet below the level of the power station. The car-sheds over the pond belong to the Tyneside Tramways and Tramroads Co., to whom the Supply Co. will supply current in bulk. On the other side of the power-house is the testing pond, which is capable of absorbing 1,500 kilowatts. The overhead line (low tension three-phase, and direct current) leaves the power-house on this side; it is used for a supply of current to the Neptune Engine Works (Messrs. Wigham-Richardson and Co.), and the Walker Shipyard (Sir W. G. Armstrong, Whitworth and Co.).

Boiler-House.—There are four batteries of Babcock and Wilcox boilers installed. The batteries consist of two boilers of about 1,000 H.P. capacity each, and are fitted with superheaters, mechanical stokers, &c. The working pressure is 200 lbs., and the superheat 100° F. to 120° F. Each boiler has a heating surface of 4,020 square feet, and will evaporate 14,000 lbs. of water per hour. An electric locomotive (20 H.P.), is used for conveying coal to the boiler-house from the railway. Amongst the fittings is an apparatus for determining the quality of the flue gases. The ashes are discharged into trucks in the ash tunnel and thence raised by an elevator at the south-east end of the house. A Green's Economiser, with 280 tubes and usual motor driven scraper gear, serves to heat the feed-water before entering the boilers. The steam-pipes are of solid drawn steel tube, one main header of 7 inches diameter supplies the main engines, a separate header being used for the auxiliary engines.

Engines and Generators.—At present there are nine sets varying from 50 to 1,500 kilowatts.

Sets Nos. 1 *and* 2.—The engines of these sets are of 300 H.P., and are of Messrs. Belliss and Morcom's well-known enclosed type. They drive two direct-current generators, supplied by the British Thomson-Houston Co. These sets are used for supplying the direct-current network in Walker and Wallsend. The engines are compound two-crank type, and run at 380 revolutions per minute. The generators are compound wound, and provided with equalising switches. The armatures are slotted and are drum wound. The magnets are of mild steel.

Set No. 3.—This set is of 50-kilowatt capacity, and generates current at 240 volts for exciting purposes only.

Set No. 4.—This set is used both as a balancer and as a motor generator. The high tension side consists of a synchronous motor which drives two compound wound generators. It was supplied by Messrs. Richardsons, Westgarth and Co. The total capacity of the two direct-current generators is 150 kilowatts.

Set No. 6.—The engine, which is of 1,400 H.P., was built by the Wallsend Slipway and Engineering Co., and is of the marine type, with Corliss valves and Proell governor for normal working at 100 revolutions per minute. When the speed exceeds 115 revolutions per minute, an Aspinall emergency governor comes into play. The cylinders of this engine are 17½ inches, 28½ inches, and 48 inches diameter respectively, stroke 36 inches. The specified variation from normal speed when load is thrown off is 5 per cent., the normal variation was specified not to exceed 2 per cent., and at the official trials the variation in speed was within the limits named. The generator, 750 kilowatts, was built by the General Electric Co. of America, and wound so as to give 2,500 volts (the original working pressure), or 5,500 volts, at a periodicity of 40 cycles per second. The armature is built up of soft grade sheet iron, and is ventilated by means of spaces which allow a free circulation of air in contact with the winding. The form wound armature coils are laid in slots, of which there is one per pole per phase. The pole pieces are built up of high permeability punchings. The field winding consists of copper strips, the magnets being excited at 240 volts. The efficiency is 95 per cent. at full load, and 91½ per cent. at half load. All

the three-phase machines are star wound, with the middle point earthed.

Sets Nos. 7, 8 *and* 9.—The engines (1,400 H.P. each) were built by Messrs. Wigham-Richardson and Co., and they have four cylinders each of 19 inches, 31 inches, 34 inches, and 34 inches diameter; stroke 36 inches. The four cranks are not set exactly at right angles, the engines being specially balanced on the Yarrow-Schlick-Tweedy system. These engines are furnished with Stumpf's fly-wheel type governor. The generators coupled to the engines are precisely similar to that driven by Engine No. 6.

Set No. 10.—This set consists of a Parson's turbine, coupled direct to a 1,500-kilowatt generator. The turbine is one of the largest yet manufactured. In it the steam expands uniformly from 200 lbs. to 1 absolute. It is provided with Parson's mechanical governor for normal running, and also with a centrifugal type governor designed to shut off steam when the turbine attains a speed of 20 per cent. greater than its normal rate. The condenser and the air-pump are situated immediately below the turbine. The air-pump is of Messrs. Parson's compound type, and is capable of producing a vacuum of 29 inches. The exhaust pipe is 36 inches diameter, this large size being necessitated by the unusually low pressure of the exhaust steam. The bearings are of white metal, with forced lubrication. During a recent test of this set the amount of steam used per kilowatt-hour was found to be 17·8 lbs., a figure which compares most favourably with engines of the reciprocating type. The generator, unlike all the other high-tension machines in the station, has a revolving armature with fixed fields. The collector rings are insulated from the wooden sleeve which carries them by means of mica.

Switchboards.—The high-tension switchboard was erected by Messrs. Ferranti and Co., of Hollinwood. The main feeder switches have oil breaks, the remainder break in air. The board is furnished with the usual synchronising gear in duplicate, also British Thomson-Houston wattmeters and Ferranti ammeters. Below the high-tension switches are the field switches, provided with carbon breaks, also the hand wheels for regulating the field resistances. A subsidiary

switchboard is erected in a building on the north side of the power-house. The main high-tension feeders, which are coupled up to this board, are furnished with spark gaps, connected across the cores and also to earth; their object is to allow a discharge to take place in the event of the normal voltage being exceeded from any accidental cause.

The low-tension switchboard, which was erected by Messrs. A. Reyrolle and Co., of Hebburn, is provided with three sets of busbars —one set is in connection with the low-tension network, one set is used for exciting purposes, while the remaining set is used to supply the station lighting and power. In addition to this main board there are two sets of low-tension panels, situated beneath the gallery; these are respectively for the equalising and starting switches, and for the low-tension meters. Behind the board are the lightning arresters in connection with the overhead line.

Sub-stations.—There are at the present time four principal sub-stations in the Newcastle area, in addition to one at Wallsend owned by the Walker and Wallsend Union Gas Co. Besides these, each of the large manufacturers has a sub-station, containing static transformers and high-tension switch-gear.

In the Manors sub-station, which is a typical example of these buildings, there are installed two 500-kilowatt motor generators, one 75-kilowatt induction motor generator used for starting the large synchronous sets, and one 25-kilowatt balancer. The high-tension switchboard is of Messrs. Brown Boveri's standard type, and was supplied by Messrs. Richardsons, Westgarth and Co. The switches, which are situated in the basement of the building, break in oil, and are so arranged that they can be manipulated from above, thus obviating the necessity of having high-tension connections on the gallery. The board is furnished with synchronising lamps and voltmeters connected to transformers in the usual manner. In addition to the voltmeters and ammeters, there is an indicating kilowatt-meter and a direct-reading power-factor indicator, both supplied by the British Thomson-Houston Co. There is also an induction meter for

measuring the units supplied to the station. All these instruments are connected to transformers placed in the basement.

The low-tension board is arranged with the positive and negative panels placed on either side of the central neutral panels. On the back of each set of panels three busbars are mounted, any one of which can, by means of the plugs and switches in front of the board, be connected to any feeder or generator. Below the switchboard gallery are the field switches and main generator fuses. The sub-stations are all inter-connected by special cables, so that any portion of the network can be supplied from any sub-station.

The station at Pandon Dene, which, previous to the completion of the transmission line from Wallsend, was used as a generating station, is now being converted into a sub-station with motor generators similar to those in use at Manors.

NEWCASTLE-UPON-TYNE AND GATESHEAD WATER SUPPLY.

The history of Water Works, with their gradual adaptations to the circumstances and requirements of successive generations, may be regarded as a not unfaithful record of the advancing prosperity and civilisation of society. Viewed in this light, it becomes interesting to trace the progress of undertakings of this nature, and to contrast the simple operations which sufficed for the necessities of one age, with the bold and extensive projects demanded by another.

Previous to 1698–9, when the first Act of Parliament was obtained by William Yarnold, an attorney, from New Woodstock, in Oxfordshire, to supply the town with "good, wholesome water," the inhabitants were not altogether destitute of water; for in the historical records of the town mention is made of conduits having from time to time been formed, communicating with the springs in the neighbourhood, whence the water was brought to the public

fountains erected in the streets. The great source, however, of supply for the general domestic purposes of the inhabitants was the River Tyne, from which, of course, it had to be carried, while for drinking water the street fountains or pants were resorted to.

After obtaining his Act of Parliament, Yarnold lost no time in commencing operations near the village of Coxlodge, about 4 miles north of Newcastle, where some time previously a spring of water had been tapped by means of a bore-hole, and which was found to yield about 75,000 gallons every twenty-four hours. After constructing a small reservoir there, and laying down a 4-inch wooden pipe a distance of 5,400 yards to a place called Holmes Close, in Gateshead, he made two reservoirs at this latter place, into which the water was sent by pumps erected at the Coxlodge Springs. From Holmes Close, the water flowed by gravity through a 5-inch elm pipe into Newcastle, where two large leaden cisterns were erected for receiving the water. From these cisterns the water was afterwards distributed by means of pipes along the principal streets. About the year 1730 Yarnold disposed of his entire undertaking to a joint stock company, who acquired the Heworth Mills and Springs at Gateshead, and obtained permission from the Newcastle Corporation to construct a reservoir at the south end of the Town Moor, into which the water from Coxlodge was conveyed. It continued to supply the town until the year 1797, when the works were purchased from the joint stock company by the proprietors of the Newcastle Fire Office, who continued to supply the town from these works until 1805. In that year they purchased a field near the north end of the Town Moor, and sank a shaft which communicated with the workings of a disused colliery in which a large quantity of water was found.

A windmill was erected, and the water pumped into the reservoir on the moor. This was now the supply to the town, while the Heworth Springs supplied Gateshead. It does not appear that any scarcity of moment was experienced in the supply of water until after the year 1831, when, owing to the unusually mild winter of 1831–2, the hitherto inexhaustible underground reservoir at Coxlodge, and the springs at Heworth, were completely dry. To remedy the deficiency for the future, the company proceeded to sink another

shaft near their works at Coxlodge, by which they obtained a considerable quantity of water, though of inferior quality.

In 1832 there appeared the Newcastle Subscription Water Company proposing to take their whole supply from the River Tyne. In Parliament they were strenuously opposed by the old company, but, notwithstanding the strong opposition, the Bill of the new company passed both Houses of Parliament and received the Royal Assent in 1834. The works of the Subscription Company were proceeded with vigorously, and were brought into operation in 1835. They were designed to afford a supply of 400,000 gallons per day, pumped from the River Tyne at Elswick, the daily consumption at that time being about 80,000 gallons. In 1836, after a keen competition, the older company gave way, and the works were sold and transferred to the Subscription Company.

In 1845, a new company, afterwards called the Whittle Dean Water Company, was formed, its object, as stated in the prospectus, being to divert two of the tributary brooks which flowed into Whittle Burn, distant about twelve miles from Newcastle, and to form large impounding reservoirs. The Subscription Company transferred their works by agreement to the new company, and an Act was obtained from which the present company dates its inception. The works undertaken were completed and brought into operation in the latter part of 1848, and consisted of five reservoirs formed in the valley of the Whittle Burn, and having a capacity of 215 million gallons, the drainage area being about 3,600 acres.

The works were found sufficient until the year 1850, when the consumption had increased to $1\frac{1}{2}$ million gallons per day. The reservoirs could then only hold a supply for about five months, and in consequence of a drought, which commenced in February of this year and lasted till the end of October, the company was obliged before the end of the summer to have recourse to the old works and pump from the Tyne. In 1851 the storage was increased to 330 million gallons by the construction of further reservoirs at Whittle Dean, and water obtained from an additional 1,000 acres. Water was also first taken from the River Pont by agreement. In 1852 the consumption had increased to 2 million gallons, and in

1853 to $2\frac{1}{2}$ million gallons per day. In the latter year the supply having failed, recourse had again to be made to the Tyne at Elswick. These works were removed to Newburn in the following year, where water could be obtained above the tidal flow of the river.

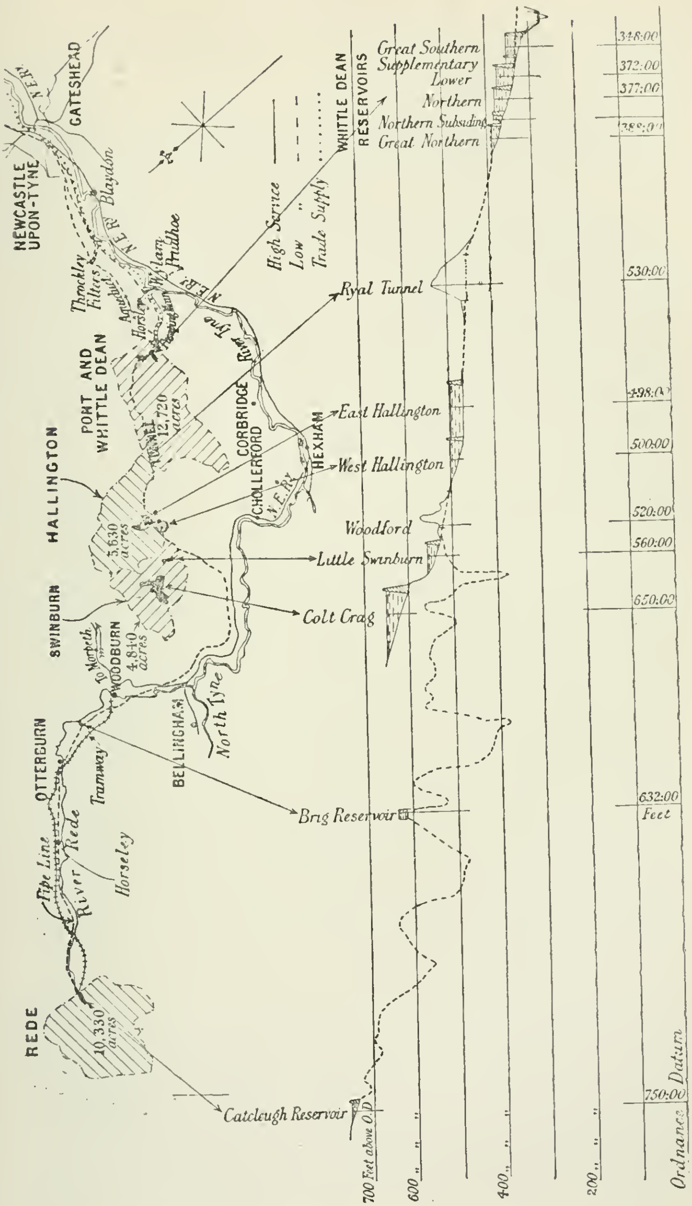
In 1854 power was granted the company to take the waters of the River Pont, Small Burn, and Hallington North and East Burns by means of an open course to the Whittle Dean reservoirs. By this time the reservoir storage had been increased from 215 to 530 million gallons and the drainage area from 3,600 to 17,300 acres.

Increased consumption, which had risen to $4\frac{1}{2}$ million gallons per day in 1862, repeated droughts, and consequent failures of supply, made it necessary for the company to apply to Parliament in 1863 for power to construct East Hallington reservoir to impound the storm water of the Hallington Burns, thereby adding 685 million gallons to the storage. Advantage was taken of this Act to incorporate the company by the name of "The Newcastle and Gateshead Water Company." Prior to this time the whole of the water, including that obtained from the Tyne, had been delivered to the consumers unfiltered, and it was not until 1870 that Parliament imposed upon the company the necessity of filtering all river water. In 1860, however, the company upon their own initiative began to construct filter beds at Benwell to filter the water pumped from the river, that obtained from their gravitation works at Whittle Dean and Hallington being considered sufficiently pure. These filters were completed in 1863, and continued in use till 1874, when it was found necessary, on account of the increasing flow of the Tyne, to remove the pumping station farther up the river to Wylam, where there could be no possible chance of fouling the water. The years following the Act of 1863 appear to have been exceedingly dry, the company passing through a succession of droughts, and having repeatedly to resort to the Tyne for water, until, in 1876, an extensive scheme was laid before Parliament, whereby the company was empowered to impound the waters of the Dry Burn and Small Burn by means of two reservoirs—Little Swinburne and Colt Crag

reservoirs—and to construct West Hallington reservoir, increasing the storage capacity of the reservoirs from 1,216 million gallons to 3,061 million gallons and the drainage area from 17,300 acres to 22,140 acres. A clause was inserted in this Act providing for the filtration of all water for domestic use, the company at the same time obtaining permission to lay down separate mains for the supply of river water for trade purposes. The 24-inch main laid in 1848 was used to convey the water from the Great Southern or Trade Reservoir at Whittle Dean—into which it is pumped from the river at Wylam—into the town, where it is distributed to the manufactories on both sides of the river. Filters were also constructed at Throckley, distant 6 miles west of Newcastle, these being added to as occasion required.

The company subsequently obtained Parliamentary power to impound the water of the River Rede at Catcleugh (page 609), and to construct large filter beds at Whittle Dene. The line of 30-inch diameter pipes conveying the Rede water from Catcleugh to an existing aqueduct at Woodford is 26¾ miles in length, and was brought into use in the year 1898. The Catcleugh reservoir is still in course of construction. When completed it will add 2,345 million gallons to the storage capacity, and 10,330 acres to the drainage area of the company, thus making a total of 5,406 million gallons and 32,470 acres respectively. The present daily average consumption is 19 million gallons, and the population supplied is about 512,000.

For the early history of the Water Supply, information has been obtained from the "History of the Water Supply of Newcastle-upon-Tyne," reprinted from the "Newcastle Chronicle" in 1851, and also to a Paper read at the Meeting of the British Association in 1863, by the late Secretary of the Water Company, Mr. D. D. Main.



Plan and Section of Reservoirs and Pipe Line.

THE NORTH EASTERN MARINE ENGINEERING CO., WALLSEND-ON-TYNE, AND SUNDERLAND.

The Northumberland Engine Works and Forge of this Company are situated on the River Tyne, at Wallsend, midway between Newcastle and Tynemouth, and about three minutes' walk from Point Pleasant Station on the North Eastern Railway Company's riverside line, and fifteen minutes' walk from the same company's Wallsend Station on the Newcastle and Tynemouth main line, and five minutes' walk from the Tyne General Ferry Co.'s Wallsend boat landing.

The Tyne outrivals most, if not all other rivers, Clyde and Thames included, for from Elswick to the sea the river fairway is a continuous line of shipyards, foundries, and engineering works, which have played important parts in the institution and maintenance of England's maritime ascendancy; and the Works of the North Eastern Marine Engineering Co. may be fittingly instanced as representing an important factor of that operative interest, so far as the manufacture of marine engines and boilers is concerned. The Wallsend Works were built in 1882 to meet the actual and possible requirements of the trade, and they may be considered as one of the most complete and perfect marine-engine and boiler works on Tyneside; the Works afford every advantage and resource necessary for the prosecution of the business of marine engineering. They are also within easy distance of all the principal shipyards and docks on the river.

The main buildings consist of a symmetrically arranged block of substantially built brick buildings, flanked by the company's railway sidings on the east and west, by the River Tyne on the south, and by the North Eastern Railway Co.'s Riverside and Tynemouth main lines on the north. The principal block comprises six lofty bays with the offices and stores in front. The shops are so arranged as to provide for the regular progression of the work

from the initial to the finishing stages, thence to its position on board ship, with a minimum of labour and a maximum of expedition; the works include a forge, iron and brass foundries, brass finishers' and coppersmiths' shops, pattern shop, &c., and they are thus in a position to execute every detail of their manufacture on the spot, without seeking outside assistance.

The whole of the machinery in the works, including some 20 overhead cranes, varying from 10 to 80 tons, as also the 100-ton sheer-legs, and 25-ton jib-crane on the quay, are driven electrically on the continuous-current system at a voltage of 250. There are about 100 motors, ranging from 5 to 50 horse-power each, the total horse-power aggregating about 1,500. The power is taken from the Newcastle-upon-Tyne Electric Public Supply Co., which transmits the current from their Neptune Bank Power Station, Wallsend (about $1\frac{1}{2}$ miles distant), to the sub-station adjoining the company's Northumberland Forge, where it is converted from 3-phase 6,000 volts to continuous current at 250 volts.

The total area of the company's property, including the foremen's villas and workmen's houses (which belong to the company and were built for the convenience of their workmen), is about 30 acres. Since the formation of the company about 1,500 merchant and war-vessels have been engined in the works. The general entrance is from the north by a wide covered passage overlooked by the timekeeper's office and general store. On the right and left are flights of stairs leading to a gallery or landing giving access to the commercial, estimating, correspondence, and drawing offices, and to the manager's and private offices, and Board Room. The drawing office and fireproof room, in which all drawings are kept, together with the tracing loft and photo rooms above same, are of recent construction.

Proceeding from the offices to the workshops by way of a covered passage, members enter the large machine and erecting shops, whose lofty bays are 350 feet long, by 60 feet wide, each having a floor space of 21,000 square feet. They are fitted with overhead cranes, travelling the whole length of the shops, driven by 3 and 4 motors, and capable of lifting up to 80 tons. The tools are of the most

improved type and of the heaviest description, including milling and band-sawing machines for cutting cold iron and steel, and a wall planing machine capable of planing 25 feet horizontally and 15 feet vertically. The erecting pit or shop is at a lower level, to allow of complete erection of large engines, which engines can be moved bodily to the quay and shipped in one lift. The special railways, from erecting and boiler shops to the quay, are 7-foot gauge, for the conveyance of heavy weights, which, on their way to the quay for shipment, pass over a large weighbridge of 120 tons capacity.

To the west, and corresponding in length with the machine shop, is the iron foundry, with its adjuncts in the way of a commodious brass foundry, brass finishing shop, coppersmiths' shop, and tool fettling shop and tool store. On the east side of the erecting shop is the small machine shop and fitting gallery, also blacksmiths' shop containing 19 fires and 2 steam-hammers, and the boiler-making department, in which will be found some exceptionally powerful machinery and hydraulic plant, capable of manipulating steel plates up to two inches thickness. The pattern shop is a detached building to the south of the iron foundry, and is fitted with the latest types of wood-working machinery.

The river frontage to the works is over 700 feet long, and, to enable vessels of the largest tonnage to lie afloat whilst receiving their machinery, the company has built a substantial jetty, the whole length of the frontage, on which quay are a pair of 100-ton electrically driven sheer-legs, and a 25-ton electrically driven jib-crane (the only one of the sort in the United Kingdom) for lifting the machinery in and out of the vessels. The quay is served by lines of rails connected with all the principal shops and sidings, and to the forge, and to both main and riverside lines of the North Eastern Railway; the company run their own locomotives, conveying material, etc., to and from the Works. The output of indicated horse-power of marine-engines during the last few years has been the largest in the United Kingdom of any firm under one management. The number of hands employed at the Wallsend Works is at present about 1,750, and at the Sunderland Works about 1,200.

The Sunderland Engine Works, which were founded in 1865, occupy an advantageous situation on the eastern side of the South Docks, Sunderland, and cover an area of more than four acres in extent. They consist of a series of commodious buildings, comprising engine shops, boiler works, smiths' forge and iron foundry, besides pattern shops, brass foundry with brass finishing departments, coppersmiths' shops, and all other departments necessary for the turning out of first-class work. All these shops are fitted up with powerful machinery of the most modern adaptation to its various purposes, and capable not only of producing marine engines, up to the largest size, but of doing so with the utmost possible despatch. In addition to their general business, the firm are also well known as being the sole manufacturers of several specialities, of which they are also the inventors and patentees, amongst which may be particularly mentioned their feed-heater and cleaner, an evaporator, a duplex donkey-pump, and stern tube arrangements for propeller shafts, all of which have been proved by actual service to be of immense practical use for their purposes; the annual output of these specialities shows a steady increase since their respective production.

PALMER'S SHIPBUILDING AND IRON CO., JARROW-ON-TYNE.

These works are situated on the south bank of the River Tyne at Jarrow, about seven miles from Newcastle, and were founded in 1851 by Sir Charles Mark Palmer, Bart., M.P., and his brother George Palmer. The firm was converted into a company in 1865, Sir Charles being its chairman until his retirement in 1893. The works cover an area of about 100 acres, and have a river frontage of nearly three-quarters of a mile. They consist of a shipbuilding yard, graving dock and slipway, engine and boiler works, steel works and blast-furnaces, and include within themselves the entire range of operations from the smelting of the ore to the complete equipment

of the vessel. There are about 8 miles of railway within the works, which are connected by private lines with the North Eastern Railway.

The shipbuilding yard was established on the site of an old yard where wooden frigates had, early in the century, been built for the British Government. The first iron vessel that was built here was the "Northumberland," a paddle tug. The competition of the Midland coal fields in 1851 began to affect the sale of north country coal, which had been hitherto conveyed to London in small collier brigs; it therefore became necessary for the colliery owners to devise some means of conveying their produce to the Metropolis in an expeditious, regular, and economical manner. Sir Charles Palmer accordingly designed the iron screw-steamer, "John Bowes," of 650 tons capacity, and capable of steaming 9 miles per hour. This vessel proved a success, and was the fore-runner of a long list of screw colliers. On the outbreak of the Crimean War in 1854, the firm received an order for an armour-plated vessel. This ship, the "Terror," was built, armour-plated, and launched in about three months. This result was largely due to Sir Charles Palmer, who conceived the idea of rolling instead of forging the armour plates. In 1866 the Indian troopship "Jumna," the largest vessel hitherto built at this yard, was launched. In the "sixties," the company commenced building Atlantic liners, among them being the "Montana" and "Dakota," for the old Guion Line. They also commenced the construction of three large vessels of special type for carrying petroleum in bulk. In 1876 the British Government gave them an order for a series of flat-bottomed gunboats for river service. Various other orders followed for warships. In 1893 they made a new departure by accepting a contract from the Admiralty for three torpedo-boat destroyers of 27 knots speed; and a further order for six other vessels of 30 knots speed followed later, the results being equally satisfactory. One of the most recent battleships constructed here is H.M.S. "Russell," and several steamers of over 10,000 tons deadweight for the Atlantic cattle trade have recently been delivered.

In addition to numerous electrically-driven modern machines and tools, hydraulic presses, pneumatic riveters and caulkers, electric

drills, &c., the shipyard possesses its own forge and also rivet works capable of supplying the shipyard and boiler shops. There are also large fitters', plumbers', joiners' and cabinet-makers' shops, where the internal fittings required in ship construction, including steering gears, &c., are manufactured. The graving dock is 440 feet long by 70 feet wide, and some notable repairs to vessels have been executed in it.

The productive capacity of the engine works can be gauged by the fact that 34 sets of engines and boilers have been turned out in one year. The department is self-contained, having its own forge and also foundries for the production of iron, brass, and steel castings. Among the various machines in these shops are a plate edge-planing machine, capable of taking a plate 35 feet long by 12 feet wide and planing two edges simultaneously; a set of vertical rolls, capable of bending cold a shell-plate 12 feet wide and $1\frac{5}{8}$ inches thick; a 200-ton hydraulic flanger; a hydraulic riveting machine with 12 feet gap, and capable of exerting a pressure of 150 tons. The shops are also equipped for dealing with the "Express" type of water-tube boiler, and more recently a plant for the manufacture of Belleville boilers has been added. A speciality is the manufacture of the "Reed" water-tube boiler, the invention of Mr. J. W. Reed, manager of the engine works department, which has been adopted in the high-speed Jarrow boats and in vessels constructed for the Admiralty on the Clyde. Nearly 25 miles of tubes are used in the manufacture of the boilers and machinery of each 30-knot destroyer.

A feature in the iron foundry is the manufacture of ingot moulds and slag tubs, thousands of tons being turned out during the year. In the machine and erecting shops the tools are of the most modern type. In the lower erecting shops, engines of various sizes for single and twin-screw merchant vessels are built, while in the upper shop torpedo-destroyer engines to run about 400 revolutions per minute are erected side by side with engines of 18,000 horse-power. For lifting machinery and boilers on board, a new set of sheerlegs to lift 120 tons has recently been erected.

In the pig-iron making department there are five blast-furnaces with the usual equipment of hot-blast stoves. One of these furnaces

is set apart for the manufacture of Cleveland iron, principally for foundry purposes, and produces about 650 tons per week. In the other furnaces high-class hematite pig is produced for the manufacture of the mild steel now so largely used for shipbuilding, and about 1,000 tons per week are produced per furnace. The furnaces are about 80 feet high, 24 feet diameter at the boshes, and 11 feet in the hearth. The bulk of the hematite produced is transferred to the company's own steel works, where it is converted into Siemens-Martin mild steel by the acid process, the surplus iron being sold to neighbouring steel makers. In the steel works there are eight melting furnaces, each of 40 tons capacity per charge. The various mills—cogging, sectional, plate, and sheet mills—are fully equipped with the usual guillotine shears, hot and cold saws, and contrivances for saving heat and labour. There is a complete installation of electric power for driving all the outlying machinery, and also an extensive plant for electro-galvanizing.

The total number of vessels completed at these works since their establishment in 1852 is 771, and the tonnage has risen from 920 in 1852 to 61,016 in 1901. The number of men and boys employed is about 10,000.

MESSRS. SMITH'S DOCK CO., NORTH AND SOUTH SHIELDS.

This company was formed in 1899 to consolidate the businesses of Smith's Dock Co., H. S. Edwards and Sons, and Edwards Brothers, and owns large shipbuilding and repairing works on both banks of the River Tyne.

Commencing at South Shields are the High Docks, three in number, the largest of which is 430 feet in length. This yard is fitted up very completely with large plate-bending rolls, punching and shearing machines, joggling machine, steam travelling-cranes, and all the appliances usually met with in a modern repairing yard; there are also, adjoining the yard, fitters' and blacksmiths' shops,

boiler shop, and a large brass foundry, which, in addition to the repairing work, does a large and increasing outside trade in bronze tuyères, bosh plates, and other requirements for blast-furnaces.

Crossing over to North Shields, the two Bull Ring Docks are seen; both are large docks of modern construction, which are employed principally in the docking and repairing of oil-tank steamers, and which are therefore specially fitted up for that purpose. Adjoining these docks is the Shipbuilding Yard, which is devoted exclusively to the construction of steam fishing-vessels, shallow-draught steamers for coasting and river work, and similar special work. Of particular interest are the steam herring-drifters, to which the company have been devoting a large amount of attention recently, and of which they have constructed no less than forty since the beginning of last year. These vessels are built of steel and fitted with engines of large power, and are specially fitted up for the herring fishing; those which are now at work have proved extremely satisfactory in every way, and it is fully expected that in a few years' time this class of vessel will entirely supersede the old-fashioned sailing vessels in this particular trade, in the same way that the steam trawlers drove the sailing trawlers out of existence some years ago. It will be noticed that this yard is now being re-arranged and re-organized on the most modern lines; and when these improvements are completed, it is anticipated that the works will be in a position to deal with a very much larger output than was formerly possible. The whole of the yard above the building slips is being levelled and completely covered in with a glass roof; this will enable work to be carried on independently of the weather, which, especially in winter time, used to cause such frequent stoppages. New plant and machinery is also being laid down, all of which will be driven by electric motors, the power being obtained from the Corporation mains; the whole of the yard is thoroughly lighted by arc lamps.

Passing through the Shipyard, the Pontoon Docks are reached, which occupy the site of the old shipbuilding yard of Messrs. T. and W. Smith, the predecessors of the original Smith's Dock Co. This yard is now devoted entirely to ship-repairing in all its branches, and has been entirely re-organized during the last few

years, with the object of bringing it up to date and enabling repairs of every description to be undertaken. Starting at the east end is the old graving dock, which at the time of its opening was looked on as one of the finest and largest on the North-East Coast, although it has long since retired from that position. Next to this is the first pontoon dock, which was built by the company about thirteen years ago, to the designs of Messrs. Clark and Standfield, of London. This pontoon was the first of its kind to be successfully used in Great Britain, and its success was so great that a few years later it was decided to build another of similar design, but of much greater capacity. This latter pontoon is situated at the west end of the yard; it is capable of taking on vessels up to 450 feet in length by 56 feet beam, and weighing 6,400 tons. The pumps for emptying the pontoon are eight in number, each driven by a 60-horse-power electric motor. With this large pumping power it is possible to lift a vessel clear of the water in twenty minutes, and it has frequently happened that one vessel has been floated, a second one taken on and lifted for examination, re-floated, and a third one taken on and lifted, during one high water. This enables a vessel which merely requires the bottom sighted, to proceed straight on to her loading dock, should nothing be found wrong with her, a point which shipowners have not been slow in taking advantage of. The power necessary for driving the pump motors, as well as the numerous other motors about the place, is generated in a building situated about the centre of the yard, from which point the current is carried through armoured cables as required.

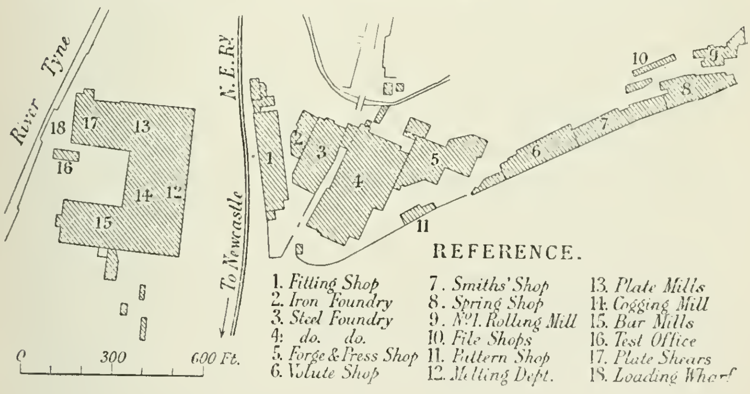
At the back of the pontoon docks are situated the various shops, fitted up with every requisite for carrying out repairs to vessels' hulls, engines and boilers, whilst between the pontoons and at each end of them, are deep-water quays, alongside which vessels undergoing internal repairs are laid. The number of men employed varies from 2,000 up to 4,000, and the number of vessels docked last year in the eight docks of the company amounted to 652, whilst the number of vessels under repair, in and out of dock, was 958.

MESSRS. JOHN SPENCER AND SONS, NEWBURN STEEL WORKS, NEWCASTLE-UPON-TYNE.

This firm was founded by Mr. John Spencer in 1810 for the manufacture of files. Newburn, with the water-power afforded by the Burn, which at that time was a good stream, attracted him as a favourable place to establish a works. The Newburn Steel Works were therefore built in 1822, comprising converting furnaces, crucible melting furnaces using coke, rolling mills and tilt hammers, driven by water-power, and file manufacturing shops.

George Stephenson was born near to Newburn, and for some years lived within the present bounds of the works. The Hawthorns

Messrs. John Spencer and Sons, Newburn Steel Works, Newcastle-upon-Tyne.



also belonged to Walbottle, which is close to Newburn. Hedley lived at Newburn, and his locomotive passed on its journey from Wylam to Lemington on the line of rails which now runs through the works. It will be understood that it was upon this line of railway that it was first demonstrated that the adhesion of a wheel on a plane surface was sufficient for traction. The original patterns

for cast-iron rail with rack teeth and pinion are still in Messrs. Spencer's possession. The whole of the raw material then used was imported from Sweden. On the introduction of the locomotive, some of the materials for its construction were obtained regularly from Newburn by Stephenson and by the Hawthorns.

The development of Newburn Steel Works followed the introduction of the railway system, the manufacture of forgings, springs, castings, etc., being extended, while the spring trade especially formed a large and busy department of the works, particularly on the adoption of Baillie's volute spring in place of laminated springs by many engineers, of which volutes Messrs. Spencer were the sole licencees. The early railways in all parts of the world were supplied with more or less of their requirements. The introduction of the steamship and its development again led to a considerable expansion of the Newburn Works, and the forges were shifted and enlarged to meet the modern demand for large crank and other shafting, gun work, etc., and were provided with large hammers and furnaces, also with a hydraulic forging press.

The machine shop is also new and quite up to date, containing powerful tools for machining marine, locomotive, and other heavy forgings and castings.

Although steel castings in simple form had been made at Newburn many years previously, it was not until 1866 that it was taken up as a specific business and developed for all purposes, the material being comparatively hard. After considerable success with mild steel castings, Lloyds and the Board of Trade, in 1879, were induced to accept the material for crank-webs, crank-shafts, anchors, and later, after an exhaustive series of experiments, for engine and shipbuilding work generally. The general adoption of stern-frames, rudder-frames, stems, also both solid and built crank-shafts, testifies to the successful use of mild steel for castings of this description.

For several years previous to 1889 material had been supplied from Newburn for rolling into mild steel plates, but it was only at the beginning of that year that the erection of the present rolling mills was begun. These mills were opened in 1891 for the

manufacture of the largest boiler and ship plates. Plates are now made of any thickness up to 6 inches, and to a maximum width of 12 feet, to meet the requirements of the several Registers and Corporations. Eight 30-ton open-hearth melting furnaces supply the requisite steel for the requirements of the mill, the output of which amounts to 1,000 tons of finished plates per week, besides bars, blooms, and billets.

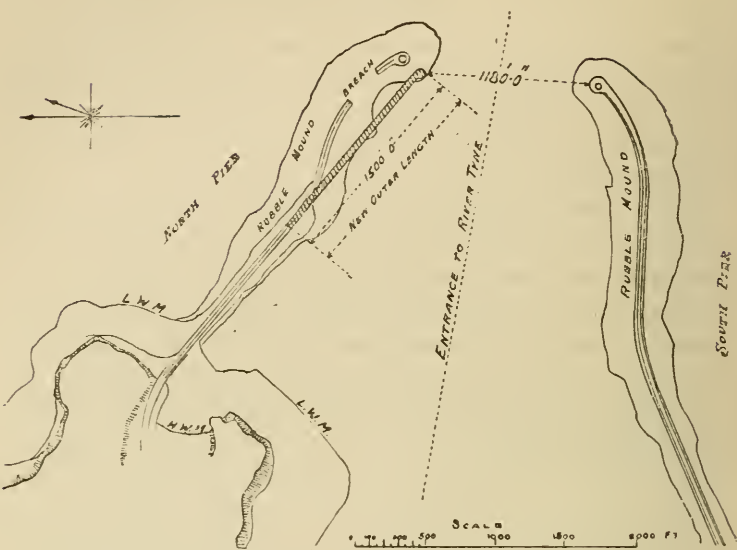
The cogging and plate mills are driven by reversing engines supplied by the Bowling Iron Co. The plate mills consist of one 30-inch and one 42-inch mill, whilst there are also 10-inch, 14-inch and 18-inch bar mills driven by separate engines. Two powerful plate shears, capable of cutting plates up to $1\frac{5}{8}$ inches and $1\frac{1}{2}$ inches respectively, are employed, the former made by Messrs. Buckton and Co., and the latter by Messrs. Crow Harvey and Co. The number of men employed is 1,500.

TYNE NORTH PIER RECONSTRUCTION.

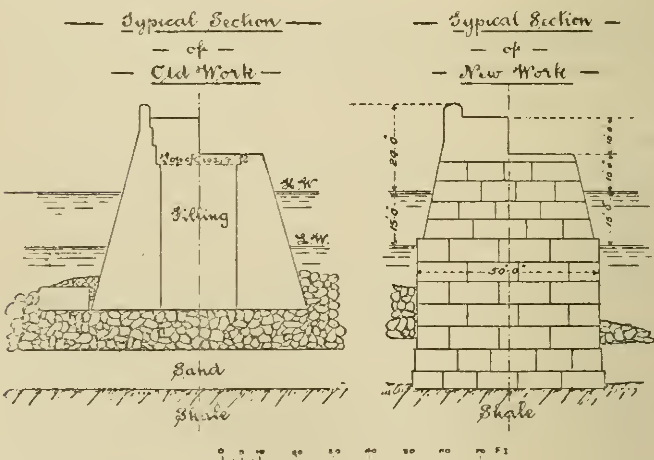
The Tyne Piers were commenced no less than forty-seven years ago with the dual object of shielding the entrance to the Tyne from the rough sea and of scouring away the bar. They were constructed from designs originally prepared by Messrs. Walker, Burges and Cooper.

With regard to the North Pier, the straight portion, that is the shoreward half, was constructed under a contract, the contractor being Mr. Benjamin Lawton. The outer half was carried out by the Tyne Commission's own staff, under the late Mr. P. J. Messent, who had acted as Resident Engineer in connection with the first contract. The general design of the structure comprehends a mound of rubble stone carrying a superstructure of masonry. The latter consists of two longitudinal walls, connected at frequent intervals by cross walls, the cavities or "pockets" thus formed being filled near the shoreward end with quarry debris, and further seaward with mass concrete.

— Fig. 1. —


North Pier
Rubble Mound
Breach
1500' 0"
New Outer Length
1180' 0"
Entrance to River Tyne
Rubble Mound
South Pier
L.W.M.
H.W.M.
L.W.M.
Scale
500
1000
1500
2000 Ft

— Fig. 2. —


Typical Section
of
Old Work
Typical Section
of
New Work
H.W.
L.W.
Filling
Sand
Shale
24' 0"
15' 0"
50' 0"
10' 0"
Shale

The depth of the foundations of the superstructure varies from low-water level at the shoreward end to 27 feet lower at the pierhead. This depth of foundations at the pierhead is much greater than was originally contemplated, it having been discovered, while the work was in progress, that wave action took place at much greater depths than had previously been supposed. The depth of the foundations would probably have been carried still lower had it not been that the rubble mound had been deposited very much in advance of the work, in order to insure its being sufficiently consolidated before being built upon. The whole work seems to have stood well until the winter 1893–4, after which it was found that some of the foreshore blocks had been moved and the foundations of a short length of pier exposed.

In spite of every effort being made to effect repairs, in the year 1897 a breach was formed completely through the pier. This has extended until it is now 100 yards in width.

Sir John Wolfe Barry, K.C.B., and Messrs. Coode, Son and Matthews were called in to advise the Tyne Improvement Commission as to the wisest course to adopt, and after careful deliberation they decided that the remedy was to construct a length of new work under the protection of the breached structure. The new work is to be 1,500 feet in length, and is to join the outer end of the straight portion of the old work, forming with it a breakwater, straight from end to end, and of a length of over half a mile, Fig. 1 (page 622).

In the new work the rubble mound is being dispensed with, and the foundations are being taken down to a hard shale, the depth averaging about 20 feet more than that of the original structure. Above the lower-water level the section of the new work is identical with that of the old, Fig. 2.

The new length of pier is being made of Portland cement concrete blocks bonded from side to side of the pier, no mass work being used except above high-water level. The heaviest blocks weigh (in air) from 30 to 40 tons, and those exposed to the sea are faced with Aberdeen granite. The blocks below low water are built without mortar joints, but they are interlocked by round joggles and other means to such an extent as to render relative

movement among them impossible. Above low water the blocks are built with mortar beds, the joints being also grouted up. The material overlying the new foundations is excavated by means of grabs, and as soon as the grab has worked down to the shale a diving bell is used to level the beds for the blocks.

The diving bell now in use is 12 feet long by 9 feet wide by 6 feet high, and four men work in it at a time. The pressure, which of course varies with the depth of water, is about 20 lbs. on the square inch above that of the atmosphere, and up to now there has been no case of sickness due to working under air-pressure. When the bed is prepared the blocks are set by helmet divers, and great care is taken to get them level and true, as if they formed part of an architectural structure above water. The reason for commencing the work at some distance seaward of the junction was to admit of work being carried on at two faces and thus extending seaward and shoreward simultaneously.

As regards temporary plant—the property of the contractors—attention might be drawn to the staging, the large "Goliath" cranes, the air-compressors for the diving-bells and to the plant designed for driving the staging piles. This piling plant stands on the staging trestles last driven when driving those next in advance, the "leaders" and ram or hammer being at the end of a cantilever. In the work-yard, the method of concrete mixing and of conveying the concrete when mixed to the block moulds is also worthy of notice. The works are being carried out by the Tyne Commissioners; the Engineers are Sir J. Wolfe Barry, K.C.B., and Messrs. Coode Son and Matthews, the Resident Engineer, the author of this brief description, being Mr. Ivan C. Barling. The contractors are Messrs. Sir John Jackson. It is expected that the works will be completed about three years hence.

THE WALLSEND SLIPWAY AND ENGINEERING CO., WALLSEND-ON-TYNE.

These works were started in 1871 as a ship-repairing establishment, and in 1874 the operations were extended to the building of marine engines and boilers. The works proper cover an area of 25 acres, and the company has an equal area available for extensions.

The Repairing Department comprises graving dock 540 feet long, one of the largest and best equipped in the country, two slipways each 1,000 feet long, and the usual shipyard sheds and machinery which is driven electrically.

The Engineering Department is provided with a very large erecting shop and machine shops with electric and steam overhead-cranes, pattern shop, boiler shop, foundries, etc., 80-ton sheerlegs, electric power and lighting, steam, hydraulic and compressed-air appliances, and other modern contrivances for economical manufacturing. In recent years many important installations of machinery have been turned out at this establishment for the mercantile marine, besides exceptional contracts such as the machinery and boilers for the Russian icebreaker "Ermack," and the Cunard Liner "Ivernia." The company has also important contracts in hand for the British Admiralty, namely machinery for H.M.S. "Odin," building at Sheerness. The machinery for H.M.S. "Challenger," a cruiser recently floated at Chatham, and the pumping installation for the Bermuda Pontoon recently built by Messrs. C. S. Swan and Hunter. Besides other work there is at present in course of erection in the shops the engines and boilers for the twin screw Cunard Liner "Carpathia," which is building on the stocks at Messrs. C. S. Swan and Hunter's. Within recent years the company has built several large engines of the marine type for generating electricity, and two examples of their work can be seen in this district, namely, at the Manors Station power-house of the

Newcastle-upon-Tyne Tramways, and the Neptune Bank Power-Station at Wallsend; and the company is at present finishing two sets of large power for the Shoreditch Vestry, London.

Members visiting The Wallsend Slipway and Engineering Company's Works would see in an advanced stage of construction two sets of triple-expansion engines of the largest size for the Manchester Corporation Stuart Street Electric Power-House, which engines are to indicate 6,500 H.P. each; and the results obtained from the other sets which have already been finished have been of such remarkable economy as to encourage the belief that the performance at Manchester will prove to be a very marked advance on the latest American practice for similar work.

Point Pleasant Station on the Riverside Line is in close proximity to the works, and the North Eastern Railway lines are extended to every department. The company employs about 2,400 workmen.

MESSRS. WIGHAM-RICHARDSON AND CO., NEPTUNE WORKS, WALKER, NEWCASTLE-UPON-TYNE.

The "Neptune" Shipbuilding Yard, Engine and Boiler Works of Messrs. Wigham-Richardson and Co., are situated about four miles to the east of Newcastle-on-Tyne, on the River Tyne, in the township of Walker. They are less than two minutes' walk from the Low Walker Boat Landing, and seven minutes' walk from the Walker Station on the Riverside Branch on the North Eastern Railway Co.'s line connecting Newcastle and Tynemouth. The works cover an area of about 27 acres; they command a river frontage of about one-third of a mile, and are immediately connected by sidings with the Riverside Branch of the North Eastern Railway Co.

Shipbuilding Yard.—This was originally started in 1842 by Messrs. Coutts, and the first iron vessel, the "Prince Albert," built in the River Tyne, was launched from the yard on the 23rd

September 1842. Afterwards the Works passed into the hands of Messrs. Miller, Ravenhill & Co., and finally, in the year 1860, Mr. J. Wigham-Richardson acquired the premises. In 1862 Mr. Charles J. D. Christie joined Mr. Richardson in partnership, in 1879 Mr. John Tweedy, and in 1890 Mr. Philip W. Richardson and Mr. J. Denham Christie. In 1899 the business was converted into a limited company. The Shipbuilding premises are divided into two parts. The South Yard, which is the oldest, contains five berths, machine sheds for the same, smith and angle and beam shops, a large timber storage pond, the general offices and stores, and a building containing a joiners' shop, pattern-making shop, moulding loft, mast-makers' shop, &c., all of which are fitted with the most modern and improved machinery. In this yard, ships up to 450 feet in length have been built for many important British and Foreign Steamship Companies. Adjoining this yard, to the north of it, is another yard, arranged for three berths, in which ships of the largest size can be built. This Yard contains, like the South Yards, spacious sheds of the newest machinery in the way of punching and shearing machines, rolls, planers, scarfers, counter-sinkers, and all the varied equipment of a thoroughly up-to-date shipbuilding works. The works are capable of turning out over 50,000 tons gross of high-class steamers per annum.

Engine and Boiler Works.—Adjoining the shipyards are the engine and boiler works, the engine works being situated between the North and South Yards, while the boiler yard is at the north end of the North Yard. This, the most modern of the three departments, consists of a large main building and supplementary buildings for machinery, and is not in any way behind the others in the completeness with which it is supplied with all the most modern and improved appliances for rapidly producing the largest and most powerful boilers, completely and perfectly finished in every respect. Amongst the appliances may be noticed three powerful overhead travelling-cranes of the latest design, numerous swing hydraulic cranes, hydraulic flanging machines, and Tweedy's boiler shell-drilling machine, by which the holes of all boiler shells are drilled

in place. There is also a complete plant for milling the edges of irregular plates, so that the caulking-line shall be truly distanced from the holes. The works, being fitted out with all the latest improvements in machinery necessary for rapidly turning out high-class work, are in a position to produce from 28,000 to 30,000 I.H.P. per annum. The number of engines built up to date is close on 400. This firm was among the very first to bring forward the triple-expansion engine, and for a number of years past they have been building four-crank quadruple-expansion engines for working at high boiler pressures, to a special design of their own. As in the shipyards, so in these works the plant is being constantly increased by the addition of the most modern labour-saving machinery, nor is any effort spared to render the establishment fully up-to-date. Recently, both in the Shipyard as well as in the Engine and Boiler Works, electric power has been used for driving a large portion of the plant, and the installation is being continued, so that before long there will be little or no steam-power in the Works. Electricity is also used for lighting purposes throughout works and offices. The current is obtained from the neighbouring Neptune Bank Power Station of the Newcastle-upon-Tyne Electric Supply Co. at Wallsend.

CORPORATION ELECTRICITY WORKS, SUNDERLAND.

There are two stations, the older being situated at Dunning Street, which turns out of High Street West, close to the Central Railway Station; the new station is in Farringdon Row, turning out of Hylton Road by the new Tramway Depôt.

Dunning Street Station comprises an engine-room 132 feet in length by 34 feet 6 inches in width, a boiler-house 77 feet 6 inches in width, and the same length as the engine room. There are also a battery room, repair shops, test room, and superintendent's offices. In the engine-room are two Willans-Holmes steam dynamos, each 26 kilowatts output at 110–160 volts for balancing and charging battery, five 125-kilowatt, and two 215-kilowatt steam sets for

lighting, and four 275-kilowatt compound-wound dynamos, coupled to Belliss engines for traction purposes. The tramway sets are surface-condensing, with a Wheeler-Barnard cooling tower; the remainder of the plant is non-condensing. There are two distinct switchboards for lighting and tramways respectively. A battery of 260 E.P.S. cells is also installed. In the boiler-house are five Hawksley Wild, Lancashire, four Galloway and two Babcock and Wilcox boilers, 130 lbs. pressure, three sets of Green's economisers; and Worthington and Weir feed pumps. A duplicate set of induced draught fans by the Buffalo Forge Co., with auxiliary chimney, is also running the day load very successfully. Coal-handling plant, by the Conveyor and Elevator Co., of Accrington, delivers the coal into a bunker, and from thence distributes it to the boilers. A water-softening plant on the Archbutt-Deeley process is also in operation.

The Hylton Road Station represents the first instalment of a 20,000-H.P. station, there being three acres of available ground. In the engine-room, 164 feet long by 45 feet wide, are now installed three 300-kilowatt triple-expansion Belliss-Silvertown direct-current sets, and two 125-kilowatt steam dynamos. The surface condensers were supplied by the Mirrlees-Watson and Yaryan Co., with a Klein cooling tower. The switchboard is very simple, and at the back in an annexe to the main building is the battery room. In this there are 130 cells; and the battery has a storage capacity of 500 kilowatt-hours. The charging and discharging is effected by a reversible booster. Above are the fitting and joiners' shops, fitted throughout with electrically driven tools, and engineers' mess room.

In the boiler-house, 164 feet long by 63 feet 6 inches wide, are five Lancashire boilers with Deighton's corrugated flues and with "Triumph" stokers, a Green's economiser of 360 tubes, two Hall's feed pumps, and a Harris-Anderson oil precipitator for the hot-well water. There is a deep well pump designed to lift 5,000 gallons of water per hour, with a 11½-inch bore-hole through the magnesian limestone into the Permian sands beneath. Coal is conveyed by a viaduct direct from the colliery, and tipped into overhead bunkers, the wagons being shunted by an electrical locomotive. The water-

softener was made by Messrs. Mather and Platt. Room has been left hereafter for the addition of superheaters, and it is proposed to add two induced-draught fans at the root of the chimney. Outside the building is the mains department's store, with smithy and tool store. It is proposed later to build the superintending engineer's house, adjoining the north gable of the engine-room.

The mains are india-rubber, bitumen insulated, drawn into stoneware casings, or cast-iron pipes; Callender's solid bitumen system is adopted in the residential district. The system is partly a 3-wire, 110-volt, but mainly a 2-wire 220-volt distribution. Arrangements are now being made for the adoption of 3-phase 5,000-volt generators and sub-stations, for the supply of shipyards, &c., and these sub-stations will also feed into the 2-wire network. The number of 8 c.p. lamps connected is 71,620, and electricity is already extensively used in the different engine shops and yards. Supply is also given to 64 tramcars, making the equivalent of 8 c.p. lamps connected over 143,000.

The car-sheds are situated, one at the north side at the Wheat Sheaf, at the north end of North Bridge Street, where there is accommodation for 60 cars, with offices and stores; and one under construction on the south side, adjoining the Hylton Road Electricity Station, where there will be provision for 60 cars, and a complete equipment of repairing shops, joiners' shops, and painting sheds. The tramways comprise 18 miles of single track completed, and 8 miles yet to construct. The gauge is 4 feet $8\frac{1}{2}$ inches, 96-lb. girder rails laid on 6-inch concrete. The system is from overhead at 500 volts. Mr. John F. C. Snell, M.I.Mech.E., is the Chief Electrical and Tramways Engineer.

WORKS OF THE RIVER WEAR COMMISSIONERS.

(*See Plate* 77.)

The River Wear Commissioners, who were first appointed in the year 1717, were empowered to undertake the control of the Harbour of Sunderland, and subsequently, in the year 1859, the Sunderland South Docks were transferred to them. Their jurisdiction extends from Souter Point on the north to Ryhope Dene on the south, over the tidal portion of the River Wear, and over a dock estate of about 250 acres. They have power to levy dues on shipping and merchandise for the carrying out of works necessary for the maintenance and improvement of the port and docks and the facilities for trade therein. In pursuance of their powers they are at present constructing two breakwaters to protect the harbour entrance, deepening and enlarging the entrances to the docks, enlarging the area of the docks, and deepening the river by dredging.

Roker Pier Works.—Roker Pier, which is situated on the north side of the Wear, is completed, with the exception of the superstructure of the roundhead and lighthouse, which are now being built. The total length of this pier is 2,800 feet. For 2,340 feet the width at the top is 35 feet, and for the remaining distance 41 feet. The width at the bottom varies with the depth—in 40 feet of water it is 120 feet wide. The top of the pier is 10 feet above high water. A subway $6\frac{1}{4}$ feet high by 4 feet wide runs the entire length of the pier, and will afford access to the lighthouse in stormy weather.

The shore portion of this pier, for a length of 385 feet, was constructed of concrete *en masse*, faced with granite blocks; for the remaining distance the superstructure is formed of granite-faced concrete blocks, varying in weight from 43 to 56 tons, set in lengths of 42 feet 7 inches each by a radial hydraulic block-setting crane, which can set a 60-ton block 60 feet in advance of its leading wheel.

The interior of each length is filled with concrete blocks and concrete *en masse.* The concrete of which the pier is mainly composed is mixed by three improved Messent one-cube-yard mixers, each capable of turning out twenty mixings of concrete per hour. The concrete is conveyed to the pier end in 20-ton boxes specially designed, so that the act of replacing them on their carriage closes the doors at the bottom of them. A 20-inch gauge railway runs from the mixers to the gearings in the blockyard, from which the concrete is tipped direct into the block moulds below. This was the first blockyard constructed with a high level gearing to avoid waste of labour, and the system has since been adopted at the construction works of the National Harbours of Peterhead and Dover. The blockyard is of sufficient capacity to make blocks for 170 lineal feet of pier.

The superstructure is set on a foundation, levelled 2½ feet above low water, which is formed of 56- and 116-ton bags of concrete deposited in the plastic state on the rock, from boxes slung in the wells of a "Wake" steam-barge and suspended from hydraulic cylinders. The bags are filled at a concrete-mixing house on the river, the barge is then moored over the site where the bag is required, the box and bag are lowered as near to the bottom as possible, and the bag deposited by the opening of the doors in the bottom of the box.

For some distance shoreward of the outer end of the pier the rock was covered with sand up to a thickness of 17 feet, and this was removed by a sand-pump suction-dredger previous to the bagwork being deposited. This dredger is not only used for cleaning the sand from the pier foundations, but is also employed on the general dredging work of the Port. It was built by Messrs. J. en K. Smit, Kinderdyk, Holland, and is 160 feet by 30 feet by 11 feet 6 inches, the suction-pipe being 21½ inches diameter and the engines 300 I.H.P. It has a carrying capacity of 600 tons, which can be loaded into its own hopper in twenty-five minutes.

The lower part of the roundhead of the pier is formed of an iron caisson, 100½ feet long by 69 feet wide by 29½ feet deep, divided into fifteen compartments by bulkheads, and set on the prepared foundation of concrete bags levelled up to 23 feet below low water. This caisson

was floated out with a draught of 22 feet containing 3,500 tons of concrete, and was sunk on its site by filling it with water. A sufficient weight of concrete blocks was placed in it, after which it was pumped out compartment by compartment and filled in with concrete *en masse* and grouted rubble. The total weight of this caisson when filled is 10,000 tons. On the top of this the upper part of the roundhead will be constructed of granite-faced blocks surmounted by a lighthouse containing a third order dioptric light, having a focal plane of 83½ feet above high water, which will be visible 16 miles. The total weight of the roundhead when completed will be 23,000 tons.

New South Pier.—The New South Pier, which is situated on the south side of the harbour entrance, is being constructed in a similar manner to the Roker Pier, but varies somewhat in detail. The length of the pier will be 2,814 feet, of which 2,163 feet is now completed; the width of this portion at the top is 35 feet, and that of the remainder will be 41 feet. The top of the pier is 9 feet above high water, and there is a parapet wall, 9 feet high by 9 feet wide, running along the entire length of the sea side of the pier so far as it is constructed. The width of the parapet wall for the remaining part of the pier will be increased to 14 feet. The weight of the blocks used on this pier is 15 tons; they are set on a bagwork foundation by a 20-ton block-setting crane worked by gas-engines. The crane revolves completely, and can set 20-ton blocks 64 feet in advance of its leading wheel. The foundation is constructed in the same manner as at Roker pier. The whole of the harbour works are being carried out by the Commissioner's workmen, under the direction of Mr. Henry H. Wake, M.I.Mech.E., the Commissioner's Engineer, and the engineering staff.

Nos. 1 and 2 Graving Dock Pumping-Stations.—The pumping plant at the No. 1 Graving Dock consists of two 83-brake horse-power (working), 98-brake horse-power (maximum) Tangye's gas-engines, coupled directly to two Tangye centrifugal pumps with suction 21 inches in diameter, and a 15-brake horse-power Tangye gas-engine, which drives a centrifugal pump, with 8 inches suction for pumping

the dock leakage. The large pump discs are $5\frac{1}{2}$ feet in diameter. In place of foot-valves these pumps have flap-valves on the delivery side of the pump. They are primed by an air-pump driven by the small engine. The large engines are started by exploding a mixture of compressed gas and air, supplied from a receiver which is charged by means of a compressor, connected when required to the small gas-engine by a clutch. At a trial made in 1895 the two large pumps discharged 10,238 tons of water in 1 hour 58 minutes, the consumption of gas by the engines being 6,695 cubic feet, the average number of revolutions of the engines per minute being 125. Two men and a leading hand attend to this pumping plant and the pumping plant at the No. 2 Graving Dock, which consists of three 120-brake horse-power Crossley gas-engines, coupled to three Gwynne centrifugal pumps, 22 inches in diameter.

Centrifugal pumps direct driven by means of gas-engines were first designed for and adopted at these docks, and the system has been generally extended to other graving docks, as it has proved an economic success.

The cost of gas (at the price of 1*s.* 6*d.* per thousand cubic feet) used in pumping out No. 1 Dock varies from 6*s.* to 9*s.* according to the state of the tide and the size of the vessel occupying the dock; this practically also refers to No. 2 Dock.

No. 21 *Coal Staith.*—The Commissioners have recently constructed a new coal shipping berth with a high-level shipping staith worked by gravity. This staith can load 1,000 tons per hour. There are four spouts, each of which is capable of being radiated 10 feet in either direction, and coal can be delivered into vessels 36 feet above the water level. The berth is suitable for vessels up to 600 feet in length, and has a depth of 30 feet at H.W.O.S.T.

No. 3 *Gateway Hydraulic Installation.*—This installation comprises hydraulic machinery for working the gates and the swing bridge over No. 3 entrance to the Hudson Dock North. The pumps which force water into the accumulator, loaded for a pressure of 700 lbs. per square inch, are worked by gas-engines. This makes the cost of

working extremely low, the cost of gas for a tide's work being only $5\frac{1}{2}d$. This machinery will also supply pressure for working the gates at the new No. 1 Entrance.

New Dredgers.—For the purpose of increasing the depth of the River, the Commissioners have recently had built in Holland by Messrs. A. F. Smulders two stationary bucket-dredgers, each 129 feet 9 inches long by 24 feet 9 inches by 10 feet, and capable of lifting 600 tons per hour. The bucket train consists of 42 buckets, each of a capacity of 17·75 cubic feet, and the speed of the buckets is seventeen per minute.

No. 1 Gateway.—This entrance, which formerly was 45 feet in width with 20 feet of water over the sill, has now been reconstructed as an entrance of 70 feet with a depth of 30 feet over the sill. The gates are constructed of Jarrah wood, and are opened and closed by hydraulic machinery. Under the apron is a subway for the conveyance of hydraulic pipes, gas and water mains, this system having been adopted in all entrances reconstructed at this port during the past twenty-five years. The reconstruction of No. 1 Gateway completes the reconstruction of all the entrances to the Docks which were in existence in 1850 to 1856.

Hudson Dock North Enlargement.—For the purpose of providing better accommodation for the class of large vessels which now frequent and are being built at this port, the work of enlarging the Hudson Dock North by removing $8\frac{1}{2}$ acres on the east side of the dock and the construction of a new quay wall is in progress. The depth of water over the new area will be 30 feet at H.W.O.S.T. The original depth in the Hudson Docks was 24 feet, and a large proportion of it has now been deepened to from 28 to 30 feet; the bottom being magnesian limestone rock, or marl, renders it a slow and difficult process. The construction of the new No. 1 Gateway and the Dock enlargement, which are the only dock or harbour works the Commissioners have placed in the hands of contractors during the past thirty-five years, are being carried out by Messrs. Sir John Jackson.

MESSRS. GEORGE CLARK, SOUTHWICK ENGINE WORKS, SUNDERLAND.

These works, belonging to Messrs. George Clark, are situated at Southwick, about one mile west of Sunderland Bridge. The business was commenced in 1840 at Monkwearmouth, the chief work being the manufacture of pumping and winding engines for collieries and ironworks and marine engines. The business increased so considerably that larger works became necessary, and in 1872, Southwick Engine Works were erected solely for the purposes of marine engine and boiler building. The firm have turned out engines for several of the principal shipping companies, and the works are well equipped to turn out the largest class of work.

MESSRS. JOHN DICKINSON AND SONS, PALMER'S HILL ENGINE WORKS, SUNDERLAND.

These works were founded in 1852 by the chairman of the present company. The site, which comprises about 4½ acres, is of peculiar formation, having been in former days an old ballast hill, upon the side of which the present works are erected in terraces. The different flats are excavated from the side of the hill, and secured by means of heavy concrete retaining walls.

The principal manufacture is that of marine-engines and boilers, and extensive repairing work in connection with this industry is also carried out. The boiler shop has lately been extended, and fitted with the latest type of machinery, for dealing with boilers up to 80 tons weight. The engine works are also fitted with machinery of modern type, and no expense has been spared to make the whole factory complete and fully equipped for dealing expeditiously and efficiently with the company's manufactures. There is a river

frontage of about 630 feet, and machinery is shipped from the quay on board the steamers by means of a large 80-ton crane.

The output for the last five years was as follows :—

1897.	11 sets of Engines,	representing	20,760	I.H.P.
1898.	22 ,,	,,	38,634	,,
1899.	16 ,,	,,	29,004	,,
1900.	21 ,,	,,	41,622	,,
1901.	16 ,,	,,	31,044	,,

The number of men employed is about 1,000.

SIR JAMES LAING AND SONS, DEPTFORD YARD, SUNDERLAND.

This well-known Shipbuilding Yard, which has been in existence since 1793, and is therefore one of the oldest in the country, lies on the south side of the River Wear, where the stream takes a bend in a horse-shoe shape, and the works themselves lie on the inside of the bend of the river. On entering the shipbuilding premises through the main entrance, near the offices, the road leads direct to the electrical power-house, which contains three 150-H.P. dynamos, two of which are driven by high-speed engines, and one by a compound marine-type engine. From this station the motors of the Middle and New Yards machinery, as well as the electric light installation, are driven. Passing the boiler-house, where there are two large marine-type boilers supplying steam to the electrical power-house and the joiner shop, the East Yard is reached, where there are two berths capable of taking ships up to 500 feet long. The inner berth of the two has at present a large twin-screw steamer No. 600 s.s., 510 feet long by 59 feet beam. At the bow of this ship lies the new machinery shed, a structure in two bays 250 feet long by 120 feet wide, and containing various punching and shearing machines, bending rolls, joggling, scarphing, and planing machines, &c., all driven by electric motors, and with serviceable hydraulic cranes for handling large plates. At the river end of this machine-shed lies the fitting-out quay, at which vessels, after being launched

are laid for completion, and a large travelling-crane enables material to be put on board with the greatest possible despatch. Proceeding from the quay past the bow of 600 s.s. (which vessel will be the largest ship ever built on this river), the boat-builders' shop is passed and the east end of the joiners' shop is entered. This shop is replete with the most modern machinery, driven by a compound steam-engine with shafting underground. At the lower end of this building there is a saw mill, as well as a carpenters' shop, for the conversion of the timber required for shipwright purposes.

On leaving the main entrance of the joiners' shop the road is again crossed, and the blacksmiths' shop is entered, where there are some forty fires and steam-hammers up to 15 cwts. capacity for the prompt making of various smith-work. On leaving the north end of the blacksmiths' shop, the accumulators and hydraulic pumps are seen for supplying the hydraulic cranes, riveting plant, &c., in the Upper and Middle Yards. On the right are frame-turning blocks and furnaces, and in the machine shop adjoining are various punching and planing machines, &c. Immediately in front of the turning blocks lies Deptford Graving Dock, about 320 feet long, where repairs to vessels can be promptly carried out; crossing the public road which lies at the head of the Dock, the High Yard near the store house is entered, and on proceeding to the right are two shipbuilding berths, on one of which at present is building a twin-screw steamer about 445 feet long. On the left-hand side is a large shed containing frame-turning blocks, furnaces, plate rolls, punching, shearing, scarphing and flanging machines, and other ordinary shipbuilders' plant; on passing round the machine shed and leaving the yard by the main road, the brass foundry department is reached, which comprises brass foundry, brass finishing shop, fitting and pattern shop, plumbers' shop and coppersmiths' shop, where various work in connection with the outfit of vessels built in the yards is completed. In addition to this work the foundry turns out a large amount of Admiralty work, and has facilities for casting bronze propellers up to 10 tons in weight. The firm has also Cornhill Dry Dock, situated on the north side of the river; its length on bottom is 400 feet, breadth at entrance 44 feet, and depth on sill at high-water spring tides is 17 feet.

MESSRS. JOSEPH L. THOMPSON AND SONS, NORTH SANDS SHIPBUILDING YARD AND MANOR QUAY REPAIRING WORKS, SUNDERLAND.

The North Sands Shipbuilding Yard is situated near the mouth of the River Wear, the Manor Quay Works being about a quarter of a mile higher up. The works have the reputation of being among the best kept and most up-to-date of their description on the North-East Coast. The largest amount of tonnage launched in one year has been 40,815 Board of Trade gross tons, in the year 1898, but the firm estimate the annual output of the shipyard to be 45,000 tons. They have had the honour of heading the output of tonnage on the Wear for fifteen out of the last seventeen years, and were for three years in succession fourth in the world's annual output of tonnage.

There are five shipbuilding berths, each supplied with powerful overhead hydraulic jib-cranes for hoisting plates, &c. These cranes, of which there are twelve, have a lifting capacity of 35 cwts. with a radius of action of 28 feet and a lift of 52 feet. These and the five hydraulic tower stacking cranes form quite a prominent feature in the shipyard; the latter are used for stacking plates on their edges in circular fashion round the cranes, and have a radius of action up to 34 feet and a lifting capacity up to 5 tons. Practically the whole of the hauling and lifting of material in the yard is done by mechanical power, and only steel-wire ropes are in use, the firm being one of the first on the North-East Coast to adopt hydraulic power. All the frame and beam hoisting, &c., in connection with the framing stage of a ship is either done by hydraulic or electric winches.

Mr. Phorson's hydraulic launching trigger has been used in connection with the launches since the year 1892, this being the first application of the device, which is now used in several of the leading British and Foreign shipbuilding yards.

The North-East Shed is used entirely for machinery in connection with the shell plating department. The four punching machines

are placed in close proximity to the planing, scarphing, and countersinking machines, the large rolls and Doxford joggling machine. All machines, where necessary, throughout the works, are fitted with hydraulic cranes, so that plates can be passed from one machine to another with a minimum amount of labour. The rolls just referred to are exceptionally large and of an unusual type, being so constructed that the smaller roll is on top, thus permitting of a smaller radius for bilge and other plates. Opposite these rolls is a hydraulic keel-plate bender and flanging machine, and alongside of it is another scarphing machine. The countersinking machines are of an improved pattern, capable of countersinking plates up to 30 feet long without the plates being moved, the machine itself travelling over the plate. The North-West Machine Shed is principally used for the preparation of inside plating work, and in this shed there is a spacious floor arranged for the laying-off of bulkheads and other work from plans. The anglesmiths' fires are in the West Shed, and closely adjacent to these the whole of the beam-making work is completed, there being two combined beam benders and punches, and bulb and channel section cutting machines. A hydraulic crane is used for stacking beam bulbs and angles, which it also lifts from the stacking place on to the machines. Alongside this is a latticed girder bridge for carrying the hydraulic riveting machines used for beam making.

The Machine Shed running along the head of the shipbuilding berths is used principally for punching, countersinking, planing and drilling light work. In this shed is a saw capable of cutting through cold iron 10 inches thick at the rate of 5 feet per hour. The machinery in this shed is driven by overhead shafting, the power being supplied by three 40-H.P. motors. The engine-house, containing gas-engines, air-compressors, hydraulic pumps, &c., is in the centre of the yard. In the East Shed is a large punching machine capable of punching the widest and heaviest plates required. The blacksmiths' shop is a continuation of this shed; the hammers were originally driven by steam, but are now worked by compressed air. The only steam boiler in these works is placed here, the steam from which is used for the gas-heating furnaces and the ballast

pump; the latter is used for filling and testing the ship's ballast tanks, etc. With this exception, steam is entirely dispensed with throughout the works, the power used being hydraulic, electric, or compressed air, the motive force being obtained from numerous gas-engines. At the head of this shed is a laying-off floor for light work. Further down, on the east side of the yard, the plate-furnaces and bending blocks are placed. The furnaces are heated by regenerative gas, made on the premises by special plant, and the angle furnaces in the East Yard are also heated by gas.

The East Yard is almost entirely taken up with a fine range of sheds for the frame-turning, frame-making, and floor-making departments, the whole of this work being entirely completed, including the hydraulic riveting, under the cover of these corrugated galvanized iron sheds. At the furnace mouths are placed large bevelling machines, electrically driven, the machines being capable of bevelling either acute or obtuse angles. At the entrance of the East Yard is a powerful manhole-punch and joggling machine, and beside it is a hydraulic water-course punch, and a set of straightening rolls; the manhole-punch is also used for pressing short bars which require to be set to an obtuse angle, and it is an effective plate joggler. Hydraulic cranes lift the frames which require to be riveted on to gantries, and these cranes are also used for stacking angles. There is an artesian well, which supplies the whole of the water used throughout the establishment, the well being 177 feet deep with a 6-inch bore.

The Manor Quay Works are very spacious and are used for finishing ships after they are launched, also for the extensive ship-repairing business. The joiners' shop is in these works and is supplied with all the latest wood-working machinery, all the machines being driven by electric motors. The quay frontage is 690 feet. A steam crane traverses its full length, and there is a stationary masting crane, having a lift of 66 feet in height and 15 tons in weight. The whole of the electric plant supplied to these works, including the separate lighting plant, has been supplied by the Sunderland Forge and Engineering Co., of which firm Messrs. Thompson are the principals, Mr. James Marr being managing director of both firms.

WEARMOUTH COAL CO.'S HYLTON COLLIERY, MONKWEARMOUTH, SUNDERLAND.

The sinking of this colliery was commenced in August 1897, on the site of the abandoned Wear Steel Works, on the north bank of the River Wear, about two miles above Sunderland. Part of the power plant of the Steel Works was used in the construction of the colliery, and to a certain extent is still in temporary use. Sinking operations were carried through without interruption and without encountering any serious difficulty, the Maudlin seam being passed through at a depth of 1,440 feet in December 1898, and the Hutton seam proved in the early months of the following year at 1,580 feet below the surface. The sinking was throughout practically dry, the volume of water to be dealt with never exceeding 70 gallons per minute. In the Spring of 1900 the shafts, which are three in number, were completed so far as was necessary for the winning and working of the "Maudlin" and "Hutton" seams. Two of the shafts, each 20 feet in diameter, are for coal-drawing, and the third, which is 15 feet in diameter, is intended eventually to be the fan shaft. All three are lined throughout with brick walling.

The winding engines at the east and west pits are in every way similar; the cylinders are 34 inches in diameter with a 6-foot stroke, and are fitted with Cornish or double-beat valves, the "cut-off" gear being actuated by a governor of the pendulum type driven by bevel gearing from the crank-shaft. The working steam-pressure is 120 lbs. to the square inch. The winding drums are 20 feet in diameter on the wood cleading, which is 7 inches thick fixed on steel lagging plates. The crank-shafts are hollow, of forged steel, 23 feet long and 17 inches in diameter. The drums are provided with strap brakes worked by foot levers, as well as powerful steam brakes. The winding ropes are of mild steel $5\frac{1}{4}$ inches in circumference, and are counterbalanced by endless ropes hung from the cages, the double at the bottom running loose in a groove 3 inches wide and 22 feet deep.

The pulley frames are built of steel lattice work, and are erected on solid brickwork pillars built up to the level of the heapstead floor. The winding pulleys are 20 feet diameter on the trod, the rim being built in segments and connected to the solid boss by flat tapered steel spokes. There are at present small temporary cages in use, but it is intended to replace these shortly by double-decked cages to carry four tubs on each deck. The tubs have a capacity of $10\frac{1}{2}$ cwts. of coal. There will be two levels for both loading the cages at the bottom and landing at bank, so that the two decks may be dealt with simultaneously and thus avoid "decking." The floor of the heapstead is so arranged that the tubs on leaving the cage gravitate to the tipplers, and after being emptied run to creepers at the back of the shafts, which raise them again to a level from which they can serve automatically back to the banksmen at the pit's mouth.

The heapstead is supported entirely on brickwork, the main floor being of steel girders and cement concrete, and the jigging screens and picking belts are carried by steel girders on cast-iron columns. Up to the present the output of the colliery has been entirely disposed of as unscreened gas coal, so that the sizing apparatus is not as yet required, but the coal is all passed over the belts, and any dirt in it is all picked out by hand. Both the seams now being worked provide the highest class of gas coal, practical gas tests giving an average sperm value of 631 lbs. per ton.

The main haulage underground will be on the endless rope system, the engines being on the surface and the ropes carried down the pit through collarings built into the shaft walling. Owing to serious difficulties having been met with, in the shape of large faults in the seams, the haulage is at present all done by auxiliary engines situated in the workings and driven by air at a pressure of 75 lbs. to the square inch. Ventilation will be produced by a quick running Waddle fan, 25 feet in diameter to the blade tips, and driven by a tandem compound engine having cylinders 18 and 30 inches in diameter respectively, with a 24-inch stroke. This fan and engine, now in course of erection, would probably not be running at the time of the visit of the Members. In the meantime an ample current of air is being obtained by means of a small furnace in one of the

20-foot pits, at a depth of 940 feet from the surface, which has the effect of raising the temperature of the air in the shaft to a mean of only 66° F. in winter, and producing a volume of 80,000 cubic feet of air per minute passing through the workings. There are to be two separate batteries of Lancashire boilers, $8\frac{1}{2}$ feet in diameter and 30 feet long. That at the West Pit is already in use, working at a pressure of 120 lbs. per square inch. The second battery will be put down shortly to replace the boilers of the old Steel Works.

CENTRAL MARINE ENGINE WORKS, WEST HARTLEPOOL.

(*See Proceedings*, 1893, *Plate* 58.)

These widely-known engine works, belonging to Messrs. Wm. Gray and Co., are laid out on an extensive scale, covering, as they do, an area of about ten acres, and being capable of producing engines and boilers ranging in power from 500 I.H.P. to 5,000 I.H.P. They are easy of access by road, rail, and water; they have a quay frontage of 830 feet, and new vessels from any of the local shipbuilding yards can reach this quay without having to go out of the dock system into the open sea.

The works consist of six principal departments, namely, the engine shops proper, boiler shops, pattern shop, foundry, forge, and sheer-legs department. In addition to these these are the usual auxiliary departments, such as copper shop, brass foundry, joiners' shop, painters and tool fettlers' shops, &c., so that the proprietors are able to produce every detail required in connection with the manufacture of marine engines and boilers, as well as the heavy forgings and castings of steamers. All these departments, both large and small, are laid out so as to facilitate, as far as possible, the transit of the material through the works, the machines, &c., being placed in accordance with the same idea. As a further indication of the size of these works, it may be stated that the number of men employed is about 2,200, and there is a capacity for a yearly output of from 45 to 50 sets of engines, representing about 100,000 I.H.P.

The main shops are 300 feet in length, and consist of seven spans, varying in width from 40 to 60 feet. The engine shops cover a floor area of 62,000 square feet, and the ground floor is entirely paved with wooden blocks. An ample supply of light is provided by means of wide skylights running the whole length of the building. The several bays are only divided from each other by rows of huge cast-iron columns, so that the whole department is easily overlooked by those in charge. The outside bays are galleried from end to end, and the inside bays fitted with four powerful overhead travelling cranes, driven by square shafting. Each row of columns supports a line of main shafting, and each line is driven direct by a pair of compound engines fixed snugly on the columns, thus dispensing with the intervention of a belt. Many advantages arise from this system of separate driving in departments, and still greater from the plan of direct main driving. The plant embraces machine tools of the heaviest class known, and of the most modern design.

The iron foundry consists of a commodious loam foundry, with a 63 feet span, fitted with a powerful overhead travelling crane capable of lifting 40 tons, and a centre-pillar hydraulic crane to lift 5 tons, and made to turn in a complete circle. This section is amply provided with large casting pits, a range of commodious drying stoves, covered loam stores, &c. At right angles to this is a capacious sand foundry, 320 feet long, comprising two spans of 53 feet and 26 feet respectively, the larger span traversed by an overhead travelling-crane similar to that in the loam foundry, but of lighter make. There are also four hydraulic cranes of very handy construction. Provision is made for the foundry blacksmiths, for the cleaning of castings under cover, and for the storage of patterns. The large foundry cupolas—of which there are three—are situated in the angle between the loam and sand foundries, and are thus readily accessible from both departments. The proprietors have recently added to their iron foundry facilities by the purchase of the Cliff House foundry from the late Mr. John Muir.

Adjoining the engine shop, on the opposite side to the foundry, is the boiler making department. This comprises two main bays

the same length as the engine shop, of 58 feet and 53 feet span respectively, both being traversed by powerful overhead travelling cranes. These cranes are fitted with engines and boilers, so as to be capable of independent driving. The main line of shafting in this department is driven in precisely the same manner as that in the engine department. In these shops are some powerful machine tools, a very large hydraulic riveting machine, a powerful flanging machine, and a plate-bending machine capable of bending to a circle plates 12 feet in width and up to as much as 2 inches in thickness. There is a circular annealing furnace, capable of accommodating the whole shell of a boiler after the work of welding and flanging has been completed. A speciality in the manufacture of the boilers is noticeable in the welding and flanging of the cylindrical shell plates, and fitting thereto flat end-plates, which are also welded at the corners of their seams. This method entirely obviates the joggling of one plate over another, besides having other advantages. The circumferential part of the shell consists of only two plates, and for boilers up to 13 feet diameter the end plates are in one plate only, the whole shell being thus completed by four plates. The two longitudinal seams of the shell are so placed that there are no seams or rivets under the bottom of the boiler, and, owing to the shell plates being flanged to receive flat end plates, there are no rivet heads protruding from the bottom at either of the ends. Pneumatic caulking is adopted throughout in the boiler work. In connection with these shops there is another bay, about 150 feet long by 75 feet wide, for the accommodation of the lighter work, and yet another range comprising tool store, bar-iron store, tube store, &c.

The forge and blacksmiths' department, as well as the pattern shop, are in the rear of the main buildings, the former being allocated to that position with a view to avoid, as far as possible, the ill effects of vibration in the main shops, and the latter to minimise the risk of fire. The forge includes in its equipment two 15-ton steam hammers, each provided with four 15-ton jib cranes. The waste gases from the forge furnaces are utilized for heating the water by which the boilers are fed. The forge department is

specially equipped and self-contained, having all the machine tools necessary for finishing shafting and other forgings ready for their being fitted in place in the ship. As an indication of the increased requirements of the firm in this department, it may be stated that they have found it necessary to extend their plant, and they consequently, some three years ago, took over the business of the Milton Forge and Engineering Co., which has enabled them largely to increase their output of stern and rudder frames and engine forgings. Within the last few years a drop-hammer forging plant has also been added, capable of dealing with forgings of from 1 lb. to 1 cwt., thus effecting a considerable reduction in hand-labour. In connection with this plant, liquid fuel furnaces have been adopted for heating the material.

On the quay, which is conveniently situated in front of the works, is a set of 80-ton sheer-legs, and a smaller hydraulic jib crane for the lighter weights. The North Eastern Railway Co.'s public dry dock, 600 feet in length, is within a couple of hundred yards of the sheer-legs. A powerful set of hydraulic pumping engines are daily at work on an accumulator, working at 1,000 lbs. pressure per square inch. Hydraulic power is carried into each of the departments, and is utilized not only in cranes and tools, but in lifts to the galleries and in hoisting up and down the great doors at the inlet and outlet ends of the shops. The steam generating plant is situated in close proximity to the main shops, and consists of three Galloway type boilers, adapted to work at a pressure of 205 lbs. per square inch, and fitted with Proctor's mechanical stoker and Green's economiser. These boilers are supplemented by two double-ended marine type of boilers. It is contemplated in the near future to make considerable extensions, including an electric power station. The whole of the works are lighted by electricity, but there is also a service of gas to fall back upon in case of breakdown.

The offices are large and commodious, the present drawing-office, which was re-constructed some five or six years ago, being 70 feet long by 40 feet wide, and thoroughly replete in all its details. It is ventilated by means of two Blackman fans, heated by radiators on

Ashwell and Nesbitt's system, and is lighted by electric arc lamps having inverted reflectors, which give a suitably diffused light. An ample photographic studio and record office is attached, easily accessible, and practically under the eye of the head of the department.

The first set of engines built at these works was on the triple expansion principle, and was completed in 1885. Since then business has steadily increased, the output for last year being 29 sets, aggregating 47,700 I.H.P. Some large cargo steamers have been engined at these works, including the "Rangatira," "Tekoa," "Maori," "Aotea," and "Kumara," all fitted out for the frozen meat trade, and the two latter being vessels of 12,205 and 13,165 tons displacement respectively, and each capable of accommodating about 100,000 sheep carcases; the "Cambrian," "Chicago," and "Mount Royal," vessels of 12,369 tons, 13,455 tons, and 15,800 tons displacement respectively; and the twin-screw steamer "Toronto," of 13,273 tons displacement, and having engines aggregating 5,300 I.H.P. The engines and boilers manufactured at these works have established a record for high economy of fuel, more particularly those fitted to the "Inchmona," "Inchkeith," "Inchdune," "Inchmarlo," and "Nassovia," which are fitted with Mudd's five-crank, quadruple-expansion engines, boilers working under Ellis and Eaves' system of induced draught at 267 lbs. per square inch, and the "Central" patent superheater. It is now some five years since the first vessel was fitted with this combination of specialities, and it has in the meantime been conclusively proved that a marked saving in coal consumption is effected, the average quantity of coal used per indicated horse-power per hour (as admitted by the owners of the vessels) being not more than 1 lb. This works out to $15\frac{1}{2}$ tons per day for a ship carrying 6,170 tons at $9\frac{1}{2}$ knots; or to $13\frac{1}{4}$ tons at 9 knots. In other words, 1 ton is carried 1 nautical mile on an expenditure of about one-third of an ounce of coal. Taking coal at 15*s.* a ton, 1 ton of cargo is carried over 550 miles for an expenditure of 1*d.* for fuel. Contrasted with the average performance of an ordinary set of triple machinery, this gives a saving of one-third in the coal bill. Amongst the orders in

hand are two large sets of machinery (2,500 I.H.P. each) for two oil-carrying steamers, which are being built at the Shipbuilding Department of the firm, for Messrs. M. Samuel and Co., London. The boilers of these vessels are being adapted for the burning of either coal or oil fuel.

MESSRS. FURNESS, WITHY AND CO., MIDDLETON SHIPYARD, WEST HARTLEPOOL.

This shipyard has three berths, each capable of taking a steamer up to 500 feet in length, and a graving dock 380 feet long. Next to the graving dock is the fitting and engine repairing shop, containing lathes, planing machines, drills, &c., of the most modern type, including some excellent turret, brass finishing and bar lathes. At the north end of the fitting shop is the power-house, containing engines and dynamos generating 600 horse-power for driving the whole of the machinery in the fitting shop, machine sheds, joiners' shop, saw mills, blacksmiths' shop, and a number of electric winches in various parts of the yard. At the entrance of the graving dock stands a huge crane capable of lifting 80 tons with an outreach of 40 feet.

The machine sheds cover a complete equipment of shipbuilding machinery, including a number of $1\frac{1}{2}$-inch punching and shearing machines and a 27-foot set of plate rolls. In this shed shell-plates up to 64 feet in length have been manipulated. There are in the shipyard about 3 miles of railways, which, with the large number of travelling cranes and hydraulic cranes, reduces manual labour to a minimum. The frame-turning plant and drafting boards are large enough to deal with a vessel of the size of the s.s. "Campania." The smiths' shop contains about thirty fires, two steam-hammers and one pneumatic-hammer, and has a railway through the centre which is easily controlled either by a steam travelling-crane or by the hydraulic cranes fixed in various parts of the shop.

In the South Yard a new beam shed, 200 feet by 60 feet, has just been erected, containing the most modern punching and shearing machines, beam benders, hydraulic cranes, &c. The joiners' shop is replete with circular saws, band saws, planing machines, dimension saws, &c., everything possible having been done to dispense with hand-labour. The number of men employed is about 1,000.

Among the numerous vessels built by this firm are the following:—s.s. "Manitou" (ex-"Victoria"), 475 feet long by 52 feet 3 inches, carrying 8,100 tons and steaming about 15 knots loaded. This vessel is fitted up for 120 first-class passengers, and carries 650 head of cattle, and was built to the order of the Wilsons and Furness-Leyland Line; s.s. "Chicago," of similar dimensions and speed to the above, and built for Messrs. T. Wilson, Sons and Co.; s.s. "Rapidan," 475 feet by 56 feet, carrying 11,000 tons and steaming about 11 knots loaded. This vessel carries about 840 head of cattle, and was built for the Chesapeake and Ohio S.S. Co. Two steamers, 430 feet by 48 feet, carrying about 7,700 tons and steaming 11 knots loaded, for the Manchester Liners; s.s. "Pretorian," 436 feet by 53 feet, carrying 8,400 tons and steaming about 13 knots loaded, for the Allan Line; ten steamers, 400 feet by 52 feet, carrying 8,150 tons and steaming 11 knots, for various owners. A large boat for carrying petroleum in bulk is at present on the stocks; also a steamer to carry 9,000 tons for the Hamburg-America Line.

MESSRS. WILLIAM GRAY AND CO., SHIPBUILDING YARDS AND MARINE ENGINE WORKS, HARTLEPOOL.

(*See Proceedings* 1893, *Plate* 58.)

In the shipyards are eleven berths, the smallest of which is capable of building vessels of 3,500 tons dead weight, and the larger ones can accommodate vessels up to 500 feet long and beam in proportion. Two vessels now building are 490 feet by 55 feet beam; this beam is the limit on account of the dock exits not permitting

vessels of larger beam to pass out to the sea. The yards are fully equipped with the latest up-to-date appliances, and comprise, in addition to the ordinary punching and shearing machines, bending rolls to take plates of 30 feet in length, plate-edge planing machines taking in the same length of plates, scarphing machines, countersinking machines, multiple rolls, iron saws. In addition to these the yards are equipped with hydraulic plant, comprising cold bending machines capable of bending steel plates, cold, 20 feet in length and $\frac{3}{4}$ inch thick, for manhole punching, handhole punching, angle-iron joggling, riveting, and a large number of hydraulic cranes.

All the machines are electrically driven, the firm generating 850 horse-power, having 12 dynamos on their own premises; this is distributed to the various machines, the total number of motors in operation being 104. This power is also used for driving the various appliances in the smiths' shops, saw mills, portable saws, portable pumps, portable fans, for the use of the men whilst working in hot confined spaces. The whole of the winches, numbering 30, for hoisting material on to the ships are also driven by electric power. The power is also used for working a number of portable drilling machines. Electric lights are also fitted throughout the yards, and in many of the shops. Portable cables and lights are also used inside the vessels.

The firm have also recently fitted up a pneumatic plant for riveting, drilling, and countersinking. Railway lines are laid down alongside all the berths. For the purpose of transporting material in the yards, four locomotives are employed, and twelve steam-cranes. All joiners' work, upholstery work, masts, spars, and sail-making by machinery, also model making, are carried out on the premises.

There are also two graving docks, having railways alongside, electrically lighted, and with portable electric lights for use in and under the vessels whilst undergoing repairs. After the vessels are launched they are taken alongside the quays, where sheer-legs and cranes are fitted for completing the vessels.

When in full work about 6,000 men are employed, and the wages paid in 1901 were £495,000.

MESSRS. IRVINE'S SHIPBUILDING AND DRY DOCKS CO., THE HARBOUR DOCKYARD, WEST HARTLEPOOL.

The Shipbuilding Yard and Graving Dock are situated at the entrance to the West Hartlepool Harbour, and were purchased from the founders, Messrs. R. Irvine and Co., by Sir Christopher Furness, M.P., in 1897, and turned into a company, when the shipyard and graving dock were considerably enlarged. There are three large building berths, each sufficiently large to allow vessels being built up to 10,000 tons. The tonnage output last year was 28,202 Board of Trade tons, and, with erections included, 31,731 tons.

The Graving Dock is situated in the Shipyard on the east side of the building berths, and is 380 feet long and 52 feet wide at the bottom. Railways are laid along one side of the dry dock, and a large steam-crane plies thereon, capable of lifting 15 tons at a radius of 35 feet.

On entering the Shipyard through the main gateway, a turn is taken to the left, passing the general offices and stores, which brings one to the frame-turning and beam sheds, angle smiths' shop, &c., with draughting loft over frame-turning shed. Returning, and passing the main gateway, the machine shed is entered, over which are the paint and polishing shops and rigging loft; then comes the boiler and engine-house with plumbers' and coppersmiths' shop overhead, fitting shop with joiners' shop overhead, and on the left is the graving-dock pump-house, also dynamo house, and at the end of this building is the blacksmiths' shop.

The machinery is to a large extent electrically driven, and the works are lighted by electricity; hydraulic power is used for the plate-bending machine, manhole punch, and riveting machine.

MESSRS. RICHARDSONS, WESTGARTH AND CO., HARTLEPOOL ENGINE WORKS, HARTLEPOOL.

(*See Proceedings* 1893, *Plate* 58.)

During the last half-century, this great marine engineering establishment has been intimately associated with the progress of steam propulsion. The business was founded more than sixty years ago, at Castle Eden, by the father of the late Thomas Richardson, M.P., and in 1847 was transferred to Hartlepool, the title of the firm being T. Richardson and Sons. In 1894 the business was formed into a private company, and in 1900 an amalgamation was arranged between Sir C. Furness, Westgarth and Co., of Middlesbrough, and William Allan and Sons, of Sunderland, the new company being styled Richardsons, Westgarth and Co. In the earlier days of the Hartlepool Works, the firm built a number of locomotive and stationary engines, but since 1854 their principal business has been the manufacture of marine engines and boilers, of which upwards of 1,100 sets have been constructed. The works, which are situated on the west side of the harbour, have been practically rebuilt within the past fifteen years, and comprise all the various departments necessary for dealing with the heaviest class of marine machinery.

The Pattern Shop is a lofty, well-lighted building, 120 feet long by 60 feet wide, and has recently been thoroughly equipped with the most modern wood-working machinery.

The Iron Foundry has a total length of 350 feet and is divided into three bays having spans of 53 feet, 43 feet, and 33 feet, respectively. Two 40-ton and one 30-ton three-phase electrical travelling cranes are provided for the heavy lifting, whilst fourteen hydraulic jib cranes are attached to the various columns for dealing with the smaller weights; these latter being served by a separate complete system of hydraulic pumps and accumulators. There are four cupolas supplied with air blast by Root's blowers. The Brass Foundry, which is situated in close proximity to the Iron Foundry,

is a building 70 feet long by 50 feet wide, fitted with the usual appliances, including a 3-ton furnace.

The Forge has been entirely rebuilt recently, and consists of three spans of 70 feet, 67 feet, and 67 feet, with a combined length of 310 feet. It contains 5, 4, 3, and 2-ton steam-hammers, served by four new steam cranes of 20, 15, 10, and 5 tons capacity respectively, together with the necessary furnaces, scrap cutters, and other forge machinery. Six new boilers have been erected over the furnaces to utilise the heat contained in the waste gases from the latter. The Smiths' Shop contains 24 fires, a number of furnaces, and four steam-hammers. It is provided with a liberal supply of hydraulic jib-cranes, and is fitted with the usual machine tools and appliances required in this department.

Near the Forge is a building set apart for the erection of Morison's high-speed stamp batteries, which are manufactured by the company under an arrangement with the High-Speed Stamp Co. A 1600-lb. five-head battery may be seen at work. The crushing capacity of this mill is 100 per cent. greater than the average mill on the Rand.

The Boiler Machine Shop has a total length of 270 feet, and is divided into two spans of 55 feet and 43 feet, the floor being served by two 35-ton travelling cranes, and four smaller overhead cranes. The hydraulic plant comprises one 140-ton Tweddle riveter, one 60-ton riveter, one 20-ton riveter, and a hydraulic flanging press by Tweddle. There is a very complete outfit of drilling, planing, and milling machinery, plate rolls and a circular and elliptical hole-cutting machine. The Boiler Finishing Shop is a lofty self-contained building in two spans, each of 45 feet, the length being 142 feet. One bay is served by an 80-ton steam travelling crane by Messrs. Joseph Booth, of Rodley, and it is here that the boilers, after being tubed and stayed, are tested by hydraulic pressure before leaving the works. The other bay is set apart for funnels and casings, and is served by a 15-ton travelling crane. This shop contains an annealing furnace, and is provided with all the modern machine tools necessary for the expeditious and satisfactory performance of this class of work. Both Boiler Shops are equipped with complete plant for pneumatic chipping and caulking.

The Machine Shops are divided into five bays, designated, A, B, C, D, and E.

"A" bay is 120 feet long by 50 feet wide, and is utilised by the millwrights, painters, and beltmen, and contains the plumbers' and gas-fitters' shops.

"B" bay is 360 feet long by 35 feet wide, and contains medium-sized lathes, drills, planing, and slotting machines, together with a cold band-saw for iron and steel by Messrs. Noble and Lund, a vertical milling machine by Messrs. Smith, Beacock and Tannett, and a 50-ton Buckton testing-machine.

"C" bay is 360 feet long by 45 feet wide, and is occupied by the heavier class of tools, which include a quadruple geared lathe by Messrs. Shanks, of Johnstone, 35 feet between centres and capable of turning 12 feet diameter; two 30-foot centre lathes by Messrs. Hulse and Co, of Manchester, so arranged that they are capable of taking in 60 feet between centres; three horizontal and vertical planing machines, two by Messrs. Smith, Beacock and Tannett, and one by Messrs. Shanks, the latter planing surfaces 19 feet vertical by 20 feet horizontal; vertical boring machine for cylinders of large diameter; heavy slotting machine by Messrs. Buckton, of Leeds, specially designed for crank webs; slotting machine by Messrs. Shanks, of Johnstone; large band-saw by Messrs. Noble and Lund; vertical lathe for cylinder covers, etc., by Messrs. George Richards, of Manchester; horizontal duplex boring machines by Messrs. Noble and Lund; propeller boring mill, and a large number of heavy shafting and face lathes.

"D" bay is 280 feet long by 30 feet wide, and contains Harvey drilling, tapping, and stud-inserting machines. Pipe-facing machine by Messrs. George Richards, with numerous lathes, milling machines, drills, and planers. In this bay is situated the store and tool room, which is provided with Sellars' Universal and Twist Drill Grinders, Bradley hammer, also lathes, milling machine, band-saw sharpening machines, and every appliance for dealing with tools for the various departments of the works.

"E" bay is 125 feet long by 45 feet wide, and contains lathes, etc., of medium size, turret lathes and milling machines.

The Brass Finishing Shop is 100 feet long by 50 feet wide, and has recently been entirely equipped with new machinery. The machines include a large number of capstan lathes, milling machines, turret boring mill, emery machines of various descriptions, and the usual hand-rest and drilling machines.

The Erecting Shop has a length of 175 feet and a breadth of 60 feet, the height from the floor to the crane rail being 50 feet. This department is served by two 50-ton self-contained travelling cranes by Messrs. Booth, of Rodley, and two 5-ton hydraulic jib cranes by Messrs. Hugh Smith, of Glasgow. The machines include a very large double column drilling, tapping, and stud-inserting machine by Messrs. G. and A. Harvey, of Glasgow. The Fitting Shop, which adjoins the erecting shop, has a length of 160 feet with a width of 30 feet. This department is provided with a 5-ton overhead power travelling-crane, and 3-ton jib cranes on columns, together with an ample supply of all those tools and appliances requisite for the rapid and economical execution of work of this class.

The Evaporator and Finishing Shop is 160 feet long by 40 feet wide. The tools include horizontal drilling, tapping, and stud-inserting machines by Messrs. G. and A. Harvey; key-seating machine by Messrs. G. Richards; vertical drills and emery wheels for various purposes; hydraulic jib cranes of the all-round type by Messrs. Henry Berry, of Leeds.

The Copper Shop is 90 feet in length by 60 feet wide, and is fitted with pipe-bending machines by the Leeds Engineering and Hydraulic Co., pneumatic hammer by Messrs. Piercy, of Birmingham, and the usual appliances.

The fire-extinguishing plant consists of a fixed fire-engine with pumps of the Greenwich type, and a quick steaming boiler, by Messrs. Merryweather and Sons, of London, the pumps being capable of discharging 32,000 gallons per hour. The fire-engine house is close to the dock, from which water is pumped, a complete system of 6-inch pipes being laid all round and through the works. The fire-brigade house is situated on the Middleton side of the works, and is fitted up with all the necessary appliances for sudden emergency.

Telephonic communication is arranged between the various gate-houses and the firemen's dwellings.

Sheer Legs and Outside Department.—The ships to be engined are berthed at the Central Dock, where a set of 120-ton sheer legs are situated. The dock is in close proximity to the works, and a loop line from the North Eastern Railway system leads directly into the erecting shop. The workshops at the dock consist of a building 110 feet by 45 feet divided into the usual departments, the machines consisting of drills, punching and shearing machine, power hammer, angle-iron cutting machine, etc. There are also Plumbers' Shop, Smithy, and a Joiners' Shop. The machines are electrically driven from the main generating station, and electric power is also used on the ships for portable drilling machines, etc.

Electric Motive Power.—The power required for driving the different shops is generated in a central power station, and distributed by means of electrical machinery to the different points where it is required. The central power-house consists of a brick building 110 feet by 47 feet, divided into four parts, of which (1) contains two marine-type three-furnace boilers each 15 feet by 10 feet; (2) contains two cross-compound Corliss steam-engines, each indicating 500 I.H.P. at a speed of 125 revolutions per minute, and each direct coupled to a three-phase electric generator, capable of absorbing the full output of the engine and working at a tension of 200 volts; (3) contains a single-cylinder engine, indicating 250 I.H.P., driving a 120-H.P. three-phase generator and a 150-H.P. continuous-current generator through shafting. In this part is also fixed a small motor generator of about 70 B.H.P., enabling continuous current to be generated direct from the large three-phase generators, in case the small engine is not running. An annex recently built contains the hydraulic pumps and air-compressing plant. There is also under test in this department for Messrs. Selby-Bigge and Co., of Newcastle, a 100-kilowatt generator coupled direct to a Weighton-Morison high-speed engine, manufactured by Messrs. Caldwell and Co., of Glasgow. The number of men employed is about 2,000. The firm has also works at Middlesbrough and Sunderland.

SOUTH DURHAM STEEL AND IRON WORKS, WEST HARTLEPOOL.

These Works, covering an area of 12 acres at the south end of the town, were laid out about thirty years ago for the manufacture of iron rails. In 1881 they were purchased by Mr. Matthew Gray, who remodelled them for the manufacture of iron plates; and in 1888 the manufacture of steel plates was added.

The plant consists of seven large Siemens steel furnaces, with a casting-pit in front of them, served by three 10-ton locomotive cranes, which deliver the ingots direct to four soaking pits. These are arranged in a line with the cogging mill, and ingots weighing 5 tons are withdrawn from them by a 6-ton travelling crane, and delivered by it to the live rollers of the 36-inch cogging mill; this latter is fitted with tilting gear and all modern improvements. After being rolled in this mill down to the required size, the ingots are passed on by the live rollers to a powerful set of bloom shears which cuts them into slabs of suitable sizes. The slabs are then lifted by a 4-ton locomotive crane, and transferred to bogies, which convey them to the plate mills. Of these there are three, having a combined capacity of 2,000 tons of finished plates per week. No. 1 mill is a 26-inch pull-over mill, driven by a 36-inch horizontal engine. Here the thinner plates and chequer plates are rolled. No. 2 mill is a 28-inch mill, driven by a 42-inch horizontal engine and reversed by gearing. No. 3 mill is a 30-inch mill, driven by a Ramsbottom reversing engine, having two 42-inch cylinders with 60-inch stroke, and a similar engine drives the cogging mill. There are also twenty-four puddling furnaces, with two 4-ton shingling hammers and a 22-inch forge train, to provide puddled bars for the manufacture of iron plates, which are rolled in the same mills as the steel plates. No. 3 mill and the cogging mill are in one line at right angles to the Siemens furnaces, and above them all runs a 25-ton travelling crane for

changing rolls or gearing, or lifting heavy ingots. This crane also passes over part of the casting pit, which is thus available for making large steel castings when required; but at present the only steel castings made here are steel rolls, &c., for use in the works. Steam is raised by twenty-six vertical boilers, and four large 500-H.P. Babcock and Wilcox boilers, and several Lancashire and donkey boilers. The works are also fully equipped with fitting shops, test houses, laboratory, and hydraulic machinery for the economical and rapid handling of material, and are equal in every respect to any modern works.

BAMBURGH CASTLE.

The village of Bamburgh lies on the sea-coast, fourteen miles north of Alnwick. Its ancient castle stands close to the sea on an almost perpendicular rock of black basalt, 150 feet in height, and is accessible only on the south-east side. The first erection is ascribed by the Saxon chronicles to King Ida of Northumberland, who is said to have named it Bebbanburh after his Queen Bebbe, in 547 A.D. The principal events in its early history are the siege by Penda in 642, the ravages of the Danes in 993, and numerous sieges during the Wars of the Roses. In the reign of Henry VII it fell into decay. In the eighteenth century it became the property of Lord Crewe, Bishop of Durham, who in 1720 vested the castle and manor in trustees for charitable purposes. The rash and foolish Jacobite, General Forster, and his brave sister Dorothy, are also connected with its history. Grace Darling lies buried in the churchyard of the village.

The Institution of Mechanical Engineers.

PROCEEDINGS.

17th October 1902.

The first Ordinary General Meeting of the Session was held at the Institution on Friday, 17th October 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The President said it caused him very great regret to have to again open the proceedings by referring to some sad losses which the Institution had sustained. Since the last meeting the deaths had occurred on two successive days of a Member of Council, Mr. Samuel R. Platt, and one of the Honorary Members, Sir Frederick A. Abel, Bart. Mr. Platt, who was elected a Member of the Institution in 1867, was a typical Lancashire man, one of that class of clear-headed, energetic organisers of labour who had made Lancashire what it was today. Two years ago, when Mr. Platt was elected a Member of Council, the Institution congratulated itself on having secured a representative in Lancashire who would most fully sustain its interests in that county. Mr. Platt's many engagements had prevented him from taking a very active part in the meetings for many years past, but a large number of those present would remember how cordially they were received at his works when the Institution visited them in 1875, and again in 1894. At all times he was most anxious to do everything he possibly could to promote the welfare of the Institution, and only this year he contributed to

(The President.)

the Proceedings a most valuable Paper on the Guarding of Textile Machinery. It was then hoped that for many years he would have been spared to take part in the proceedings of the Institution.

Sir Frederick Abel was another man who had done much in a quiet way to promote the high standing of the Institution. More than twenty years ago, when the Institution took up original research, one of the first subjects dealt with was the Hardening and Tempering of Steel; and the researches on these matters had not proceeded far, before it was felt that the co-operation was required, not only of engineers but of some able chemist and metallurgist. It was then that Sir Frederick Abel undertook to carry out at Woolwich Arsenal a great variety of experiments and researches on behalf of the Committee, and in 1883 he was elected an Honorary Member in recognition of the value of his work. Like Mr. Platt, he had not of late years been a frequent attendant at the meetings, but he (the President) knew that up to the last Sir Frederick was deeply interested in the prosperity of the Institution, and was most anxious to do anything he could to promote its welfare. The death of Mr. Platt occurred on 5th September, and that of Sir Frederick Abel on 6th September. At a Council meeting held on 17th September, the next meeting after the sad occurrences, the Council unanimously resolved to forward letters to Mrs. Platt and to Miss Abel, conveying condolences in the sad bereavements they had sustained. The present was the earliest occasion on which the matter could have been brought before the Members, and he was quite certain, from the way in which his remarks had been received, that all present thoroughly joined with the Council in the expressions of sympathy which they had sent.

The Minutes of the previous Meeting were read and confirmed.

The President announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following seventy candidates were found to be duly elected:—

MEMBERS.

Aitken, Charles Henry William, .	Manila.
Anderson, Percy, ...	Salt River, Cape Colony.
Baker, Ernest Folliott, . .	Portsmouth.
Coates, Victor Henry, . . .	Belfast.
Darling, John William, . . .	Keighley.
Doran, William Shreeve, . .	London.
Haggie, Robert Hood, Jun., . .	Derby.
Hoskins, George John, . . .	Sydney.
Hunter, Summers, ...	Wallsend.
McIvor, Benjamin Robert, . .	Manãos, Brazil.
Millar, Thomas, ...	Newcastle-on-Tyne.
Mitchell, Benjamin Merwin, . .	Johannesburg.
Moffatt, James Adam Scott, . .	Belfast.
Neil, Alexander, ...	Warrington.
Oldham, George, ...	Durham.
Phillips, William, ...	Wolverhampton.
Pope, William Waller, . . .	Slough.
Read, John Hudson, . . .	Newport, Mon.
Reeves, Wilfred, ...	Belfast.
Sheffield, George Harrison, . .	Newcastle-on-Tyne.
Twinberrow, James Denis, . .	Newcastle-on-Tyne.

ASSOCIATE MEMBERS.

Balfour, George, ...	Dundee.
Benington, Edmond Strangman, .	Lagos.
Bliss, Basil, ...	Frodingham.
Blyth, Ernest Blackstone, . .	Rugby.
Briggs, Robert Alexander, . .	London.
Bryant, Edward Egerton, . .	Bombay.
Buckton, William Woodyer, . .	Bedford.
Chalmers, Alexander David, . .	New Brompton, Kent.
Channon, Philip Percival, . .	Haywards Heath.
Clayton, Melville Graham, . .	Iquitos, Peru.
Coueslant, Leopold Daniel, . .	Huddersfield.
Cowan, Percy John, . . .	Lancaster.

Cruddas, William John, . . .	Johannesburg.
Excell, Maurice Stanley, . .	London.
Forbes, James Taylor, . . .	Port Said.
Francis, Adolphus Sydney, . .	Clacton-on-Sea.
French, Frederick Charles, . .	London.
Garrett, John Dunnell, . . .	London.
Gentry, Buchan Strasson, . .	London.
Groundwater, Alick George, . .	Bucksburn, N.B.
Hickinbotham, William Trussell, .	London.
Illingworth, William, Jun., . .	Bradford.
Jayawardena, Theodore Godfreid Wijesinghe, ...	Colombo.
Maria, Horacio Santa, . . .	Rosario de Santa Fé.
Mayes, Howard, ...	Southampton.
Mowat, Magnus, Jun., . . .	London.
Patey, Arthur Pettman, . .	London.
Payne, Frank Gervas, . . .	London.
Piesse, Frederick Thomas Roper, .	Katanning, W. Australia.
Rennie, John Assheton, . . .	London.
Rudolph, Oswald Frederick Hermann Leopold, . . .	London.
Rush, Charles Henry Erskine, .	London.
Shaw, John, ...	Stoke-on-Trent.
Soyres, Bernard de, . . .	Bristol.
Taylor, Dudley Foster, . . .	Birmingham.
Tennant, James, ...	Prescot, Lancs.
Thompson, Arthur Beeby, . .	Baku, Russia.
Watson, John Craig, . . .	Johannesburg.
Wilson, Leonard Herbert, . .	Pretoria.

GRADUATES.

Bennett, Francis Edgar, . .	London.
Bennett, Henry Benjamin, . .	Newcastle-on-Tyne.
Brunton, John Evelyn Cardet, .	Cochin, India.
Harman, Frederick Berkeley Bruce,	Colchester.
Hess, Adolphus Charles, . .	Leicester.

HOLDEN, PERCY, ...	Eton, Bucks.
LIMOZIN, FERDINAND LOUIS JOSEPH, .	Bocking, Braintree.
SAXBY-THOMAS, HUMBERT GEORGE, .	Leicester.
SCORER, ARTHUR BRUCE, . . .	Wolverhampton.
WOODWARD, EDWARD, . . .	London.

TRANSFERENCES.

The PRESIDENT announced that the following eight Transferences had been made by the Council since the last Meeting :—

Associate Members to Members.

HAWKS, NICHOLAS SWANSON, . . .	London.
HOLLINGSWORTH, ALLEN ALEXANDER, . .	Sheffield.
MAIN, JOHN PALMER SCOTT, ...	London.
McLAREN, JOHN ALEXANDER, . . .	Leeds.
PEDLEY, HEBER ISAAC, ...	Birmingham.
SMITH, SIDNEY, ...	Cape Town.
TAYLOR, EDWARD, JUN., ...	Stockport.

Graduate to Member.

MARSHALL, FRANK THEODORE, . . .	Newcastle-on-Tyne.

The following Paper was then read and discussed :—

"Oil Motor Cars of 1902." By Captain C. C. LONGRIDGE, *Member*, of London.

The PRESIDENT announced that, as the Discussion had not been concluded, it would be continued at an Extra Meeting which would be held on Friday, 31st October.

The Meeting terminated at Ten o'clock. The attendance was 244 Members and 218 Visitors.

PROCEEDINGS.

31st October 1902.

An Extra Meeting was held at the Institution on Friday, 31st October 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The Discussion on Captain Longridge's Paper on "Oil Motor Cars of 1902" was resumed and further adjourned.

The Meeting terminated at Ten o'clock. The attendance was 163 Members and 155 Visitors.

PROCEEDINGS.

21st November 1902.

An Ordinary General Meeting was held at the Institution on Friday, 21st November 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The Minutes of the previous Meeting were read and confirmed.

The Discussion was resumed and concluded on Captain Longridge's Paper on "Oil Motor Cars of 1902."

The Meeting terminated at Ten o'clock. The attendance was 110 Members and 92 Visitors.

OIL MOTOR CARS OF 1902.

By Captain C. C. LONGRIDGE, *Member*, of London.

In offering this Paper, the author does not wish to burden Members with details, but rather to advance for discussion debatable points in the principles of construction embodied in the latest cars. It is in this sense the various sections which follow are dealt with :—

Types of Motors.—With very few exceptions, petrol car engines are of the vertical single-acting Otto type ; variations where made consist chiefly of horizontal Ottos, or more often horizontal motors, in which one cylinder contains two pistons, between which explosion takes place, such as the Koch, Gobron-Brillié, Prétot, Hyler-White, Lucas, and a number of others.

There are, therefore, two prevailing positions and two classes of engines. As regards position, the vertical is far the more common. From the standpoint of the automobile engineer, the case stands thus :—Advocates of vertical fixing assert better accessibility and adaptation to the usual method of drive ; those of the horizontal claim less vibration,* lower centre of gravity, easier lubrication, and room for a longer stroke—a requirement for the use of alcohol and heavy oils. They might also appeal to the almost universal

* The impulse being at right angles to the spring system of the vehicle.

practice of gas and oil-engine makers. In America, there is a tendency to adopt the horizontal position,* and it is not unlikely that Europe will follow suit. Between the types of engines, the comparison stands thus: simplicity and probably economy lie with the single-acting Otto; greater smoothness of running with the one-cylinder two-piston type. From the persistency and extension of its use, it is clear that manufacturers consider this latter advantage to more than compensate for increased complication, which, after all in these small motors, is not so great.

The author himself holds that neither type is going to stay. The ultimate evolution will be the impulse-every-revolution engine. The aim of manufacturers is obviously towards elimination of change-speed gear by increasing the flexibility or elasticity of the motor. The car explosion motor has to be more and more assimilated to the character of the steam-engine. To this assimilation, there is only one successful road. To obtain steady running from the highest to the lowest speed, impulse must be multiplied; and as the number of cylinders is limited—the fewer the better †—recourse must be had to the impulse-every-revolution motor. In this belief, the author has recently patented an engine in which impulse in every cylinder is obtained at every revolution. The cycle is exceedingly simple, and, as high compression is used, efficiency and economy should result. The author had not intended to describe this engine; but, in deference to an opinion that it might add interest to the Paper, he will briefly outline the principles of construction and advantages claimed. The motor consists of two, or multiple of two, side-by-side cylinders, closed at both ends. The rear end forms the compression chamber, in which explosion takes place; the front end is an air-receiver. The front end or air-

* This year the proportion of horizontal to vertical motors is about fourteen to nine.

† The multiple cylinder motor costs more to make; uses more fuel and lubricant for the same amount of work; and requires more attention and more repairs, since there are more parts. In America, last season, 58 per cent. of the cars were multiple cylinder; this year the percentage has fallen to 52.

chamber of each cylinder is connected by a pipe or passage to the rear end or compression chamber of the other cylinder. This tube or passage is provided at both ends with valves, and serves to transfer air from the air-chamber of the one cylinder to the compression chamber of the other. The compression chambers are provided with ample exhaust-valves, and the air-chambers are fitted with automatic inlet-valves. All other valves are mechanically operated. The oil, atomized by a small compressed air-jet, is fed, under control of the governor, into the combustion chamber, at the end of the compression stroke.

The action is as follows :—Assume the piston in No. 1 cylinder to be at the end of its compression stroke, and that in No. 2 cylinder at the end of its working stroke. The front of No. 1 cylinder is full of air; the rear of No. 2 cylinder is full of burnt gases. The compressed charge in No. 1 is now carburetted and fired, the piston advances, compressing the air in front; the piston in No. 2 retreats, expelling the waste gases. At about half-stroke, the exhaust valve in No. 2 is closed, and simultaneously the inlet valves (one at either end of the inlet tube) are opened, and the full charge of air, already under compression, is pumped from the front of No. 1 cylinder into the compression chamber of No. 2. On the completion of the No. 2 cylinder compression stroke, atomized oil is injected (the Diesel engine illustrates the method) and is fired ; at starting, by the electric spark, and afterwards, perhaps, by hot surface contact ignition, oil-injection can be effected at once or gradually, as desired.

The advantages claimed are :—

1. Impulse every revolution in each cylinder without extraneous pumps.

2. Perfect cushioning and easy running.

3. Very high compression, with diluted charge and, therefore, economy.

4. Absolute immunity from premature ignition, a factor that militates against high compression in other engines.

5. High initial temperature of the charge, without corresponding rarefaction. Therefore very favourable conditions for easy ignition, rapid inflammation, and high power.

6. A method of oil injection that admits of the engine being run as an explosion at constant volume engine, or a combustion at constant pressure engine.*

7. Equal adaptability to petrol or heavier oils.

The feature that will, no doubt, be pronounced peculiar, if not objectionable, is the large proportion of exhaust gases left in the cylinder. The author, however, believes that when, as in the present case, the weight of incoming charge can be made independent of rarefaction by imparted heat, and the risk of premature ignition is avoided, the presence of exhaust gases, even to a large amount, is not detrimental, and that, in view of the higher compression used, the engine will be more economical than the petrol motors now on the market. Nearly two years ago, recognising the possibly even and beneficial effect of the presence of exhaust gas, and the great value of maintaining the compression, the author strongly recommended a motor company, with which he has some connection, to adopt governing on the exhaust (*i.e.* reducing the volume of fresh charge by retaining a portion of the exhaust), in preference to volume throttling. But the management could not be brought to recognise the economy to be obtained, and adopted volume throttling. It is some satisfaction to

---

* Patent No. 21829 $\frac{94}{}$ Gas Motoren Fabrik Deutz somewhat illustrates the claims 3 and 6. The specification states: In order to work economically with this class of motor engine, very considerably diluted mixtures may be employed, because the richer the mixture the higher will be the temperature of combustion and the greater the heat lost by conduction through the cylinder walls. But in diluting the mixture, a limit is soon reached at which the ignition becomes uncertain. According to the present invention, it is rendered possible to employ a rich mixture and thus ensure ignition, and yet to keep the temperature sufficiently low to prevent material loss, by first admitting air only under pressure or an inert gas (water vapour, exhaust gas, etc.) at the commencement of the suction stroke, and afterwards the charge of rich mixture. The quantity of combustible mixture admitted under these conditions is so proportioned that the increase of volume of the charge due to the heat generated is about equal to the volume formed in the cylinder by the motion of the piston, so that the evolution of heat takes place without material increase or decrease of pressure. When the admission of the combustible mixture ceases, the hot gases expand to the end of the stroke.

the author to find—first, that motors governed on the exhaust have since established their claim to greater economy; and secondly, that the conducted experiments of Mr. Frederick Grover, in 1894–5, bear out the views held by the author. The general results of Mr. Grover's experiments, which "show that the presence of the products of combustion in certain mixtures actually raises, rather than diminishes, the maximum pressure obtained," * are :—

(1) † That the highest pressures are obtained when the volume of air present is only slightly in excess of the amount required for complete combustion.

(2) That higher pressures are recorded when residual gases take the place of an excess of air.

(3) That when the volume of the products of combustion does not exceed 58 per cent. of the mixture, then it is explosive, provided that the volume of air is not less than 5·5 times the volume of coal gas.

(4) That the time of an explosion is much reduced when excess of air is replaced by products of combustion.

Whether these observed facts are due to increased temperature, or to some chemical action, is a point open to argument.

The advantage of high compression, claimed for this engine, opens up another and what might be termed a negative feature of present car-engines. The principle, which so greatly advanced the economy of gas-engines, has scarcely yet been applied to petrol motors. Reduction in fuel consumption is the great advantage of increased compression, or, to state it otherwise, in any given mixture, the explosion pressure produced by ignition is proportional to the charge compression. In practice there are, of course, limits to the degree to which the charge can be usefully compressed. These limits are fixed mainly by four conditions: first, the difficulty of keeping piston and valves tight; secondly, the necessity of seeing that the negative work and the increased friction due to high compression do not exceed the greater efficiency obtained (the ratio of increase in efficiency

---

* "A Practical Treatise on Modern Gas and Oil Engines," 3rd edition, 1902, page 217.

† *Ibid*, page 231.

decreasing as the pressure is increased); thirdly, the desirability of avoiding the excessive shock of a rich charge fired under high compression; fourthly, the risk of premature ignition in a highly compressed charge. It may be useful to consider how far these facts affect present practice as regards compression. A very considerable advance on prevailing compressions will have to be made before the first two causes of limitation come into play. The influence of the third factor, namely the automobile requirement of an easy running engine, is already at work. But the complete and satisfactory fulfilment of this requirement is not incompatible with the use of higher compressions than are now in use. All that is required is to reduce the richness of the charge by using less petrol, until the violence of the explosion is sufficiently reduced, the result being an easy running motor, working under the conditions of maximum economy, namely high compression and less loss of heat owing to the lower combustion temperature. Poor charges may, it is true, lead to increase in cylinder dimensions, but to obviate increased weight we may yet have recourse to steel cylinders and light water-jackets. The third consideration, namely, danger of premature ignition, is also a matter of present moment. Two ways of surmounting this obstacle to high compression may be suggested. The first is, as in the Diesel engine, to admit the petrol at the end of the compression stroke. The second method, suggested by others and the author many years ago, is a system of internal cooling by water injection. To this further reference will be made.

In the matter of piston speed, this year's engines show a general return to the earlier speeds given by 700 to 800 revolutions per minute normal running.* This gives less wear and tear on the motor, gear, and firing accessories, and less difficulty in filling the cylinder; while reserve power by acceleration is held in hand. In respect of slow, yet steady action, the impulse-every-revolution motor would possess a decided superiority.

* In the 2½-ton lorries of R. Hagen, Cologne, a single-cylinder motor with normal speed of 450 revolutions is used. Motors, depending on high speed for power, are at a disadvantage for hill-climbing or overload, since the power falls rapidly as the engine slows down.

On the whole the author sees no great novelty either in the types of engine, and very little real advance since the days of Daimler or early inventors. There is undoubtedly room for a new engine and a ready market for a good one.

Material and Methods of Manufacture.—Here, again, there is plenty of room for improvement. With very rare exceptions the present car motors are cast-iron, solid-head, water-jacketed cylinders, cast complete with valve-box in one piece. It is scarcely possible to imagine a design better adapted to give trouble in the foundry or the workshop; or one less in accordance with metallurgical requirements. A casting of this description, intricate in shape, full of angles, curves, bosses, ribs, varying thicknesses, etc., enormously increases the difficulties of moulding and producing sound castings. The number of wasters that must and do occur in the foundry, in the machine and testing shops, is quite a serious matter. Apart from this commercial objection, a casting of this design is ill-suited to its purpose. First, because the variations of thickness and the ribs between the walls produce irregular expansion and contraction. Secondly, because it almost precludes the possibility of using the best iron for the purpose, the founder naturally working with a very fluid running mixture.

While the majority of makers have been caught by the "drawing-office" solid-head, water-jacketed design, a few more practical makers, such as Panhard, Mors, and Napier, have followed the plan of casting the cylinders separate, and adding a light aluminium, or rolled metal, water-jacket. This method admits of a simpler casting, for which the best metal can be used.

On the question of what is the best metal, there is a difference of opinion. Professor Hiorns inclines to white hematite, cast in metal moulds. Theoretically this is no doubt correct, but commercially the limited output and the constant changes of design might not justify the cost of moulds, and the expense of grinding the cylinders. For these reasons, both Professor Hiorns and Professor Turner recommend, as an alternative, the use of the closest and hardest

iron that can be conveniently machined. The class of iron suggested by Professor Turner as typical is:—

Combined carbon	0·55
Silicon	1·80
Sulphur	0·10 or less.
Manganese	0·50
Phosphorus	0·75

The casting of a cylinder, where there is any intricacy of design, should be a matter for special precautions. While it is not practicable to employ a system of fluid compression, such as the Whitworth or the more recent French Harmet system (*tréfilage*), some equivalent should be sought by insisting on adequate head. Colonel Holden's opinion is that for intricate cylinder castings a head of 200 per cent. by weight, that is double the weight of the casting, should be specified by manufacturers. The author has had sufficient practical experience in foundry management to concur in the value of ample head, if present designs are followed.

In view, however, of the troubles arising from porous cylinders and for other reasons, the author favours the substitution of steel tubes for cast-iron cylinders. Lightness, strength, freedom from flaws, easy cooling,* and probably, on the whole, cheapness, are much in favour of this material for small motor cylinders. Steel tubes screwed into a cast-steel or cast-iron head should make a good job. If the output warranted the initial cost in dies, pressed steel heads could be made. But the steel cylinder itself would involve no great expense.† Some years ago, the author saw a small German motor with steel-tube cylinders, in which no running troubles were experienced. Another instance, probably known to all here, is the Holden cycle motor. The class of steel used by Colonel Holden contains 0·35 per cent. carbon, and no trouble has occurred. Messrs. Brandon and Perkins, for their Victoria motor bicycle, bore the

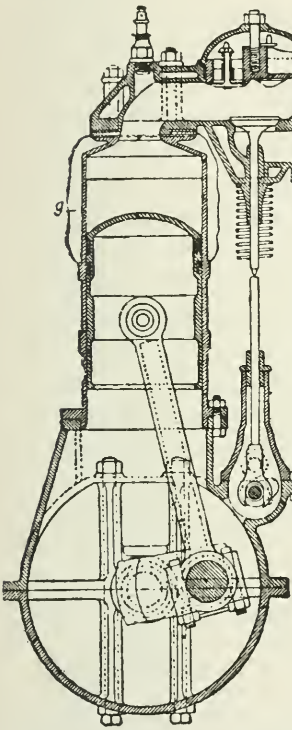
---

* An advantage enumerated in a number of patents, e.g., No. 18908$^{\underline{95}}$ F. W. Lanchester, No. 19142$^{\underline{95}}$ J. Grover, No. 23771$^{\underline{95}}$ E. J. Pennington, No. 6718$^{\underline{96}}$ F. O'Connor Prince, etc.

† Methods of building steel cylinder motors are described in several patents, e.g., No. 4618$^{\underline{96}}$ P. Mallet, No. 6718$^{\underline{96}}$ F. O'Connor Prince, No. 11491$^{\underline{96}}$ Colonel H. C. L. Holden, R.A., No. 5417$^{\underline{97}}$ S. Rolfe, etc.

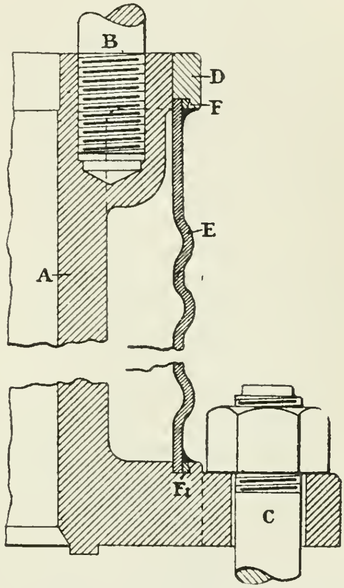
cylinders from the solid steel bar, turning the radiating fins in the lathe. Messrs. Panhard and Levassor in their Paris-Vienna type racer, run in the last French alcohol trials, are said to have used cast-steel cylinders, with a copper water-jacket. In their new

Fig. 1.—*Transverse Section of new "Centaure" Motor.*
(Messrs. Panhard and Levassor.)



The wall of each separate cylinder is of thin wrought steel; the cylinder head is an elbow tube, cast with water-jacket, and contains inlet and exhaust valves, also ignition tube. The cylinder and head are united by a scraped joint and four studs and nuts. The water-jacket g is of corrugated copper soldered to the cylinder.

Fig. 2.—*Method of attaching a light Water-Jacket.*
(American.)



A, the cylinder; B C studs securing cylinder head and frame; D iron or steel ring forced over the cylinder head and grooved to receive the jacket; E steel metal jacket; F F_1 copper wire caulked into groove black surfaces represent solder if added.

"Centaure" motor, Fig. 1, in the 40-H.P. racer of Messrs. Charron, Girardot et Voigt, and in the Canstatt Daimler racing cars, steel is the material used; and, under the severe conditions of racing, no

running difficulties have been recorded. There is really no reason why steel should not successfully and advantageously replace cast-iron. In a communication recently addressed to the author, Professor Turner wrote: "My impression is that solid drawn steel tubes would be best. They would be stronger, weight for weight, and more trustworthy." This has always been the author's opinion.

In any case, he is certain that the method of casting cylinder and jacket together is wrong; and that if the cylinder is of cast-iron, it should be cast alone, and a light jacket added, as shown in Fig. 2 (page 677). It is difficult to feel the pulse of a trade, except through its leading organ. But, judged by that standard, the view held by the author is gaining ground. In an editorial on "Detail Improvements," 14 June 1902, "The Autocar" stated: "It will be remembered that, when the aluminium jacket was first fitted to the cylinder liner, critics prophesied disaster for the Napier, as they said it was wrong to combine two metals in this way. At the same time, we feel safe in prophesying that the cylinder of the future will be built in this manner. That is to say, there will be a central liner, possibly of weldless steel, while the water-jacket will be of the lightest construction."

In using steel cylinders, cast-iron piston-rings might be retained. For these, a strong, fine-grained, elastic iron, with approximately the following constitution would be the best:—

Combined carbon	0·50
Silicon	2·00
Sulphur	0·10
Manganese	0·50
Phosphorus	0·80

Greater elasticity and resistance to external pressure is obtained by casting from pots in a chill mould.

Engine Details.—The Valves.—These are the lungs of the machine and vital to its action. The present usual practice is an automatic spring induction-valve, opened by the suction of cylinder; and a mechanically lifted, but spring-closed, exhaust valve, commonly cam-driven by a half-speed shaft. The combination is exceedingly crude, and a few manufacturers are now waking up to the advantages of mechanical operation for both valves. At the last Chicago Automobile Show, four motors, all of different makers, had

mechanically operated valves. The leading German firm, the Cannstatt Daimler Motor Co., have adopted this practice in their new Mercedes Simplex. In France, for instance, Peugeot in their new 8-H.P. car, and in England G. F. Milnes and Co., have followed suit; and there can be little doubt that other makers will be forced into line.* There is, of course, nothing new in mechanically operated valves for explosion engines. Quite a number of patents for valve actuation by magnetic attraction, compressed air, exhaust pressure, &c., &c., have been registered in past years, but so far few automotor makers have recognised the advantages of the system.

There are several reasons why with high-speed motors mechanical operation of the valves should be adopted. Owing partly to clearance and partly to back-pressure from the silencer, the cylinder at the end of the exhaust stroke is filled with burnt gases above atmospheric pressure. When the piston, therefore, begins the induction stroke these have to expand before air can be drawn in by suction, hence one of the disadvantages of the automatic inlet-valve is that it is sluggish in opening. This is just the reverse of what should be. For in high-speed motors the valve should not only open promptly at the very beginning of the stroke, but might preferably be given a "lead," thereby promoting scavenging of the combustion chamber. Again, the automatic valve closes at the end of the suction stroke, whereas it might be better to keep the inlet valve open a trifle after the piston had begun the compression stroke, that is, before the slight vacuum in the cylinder has been converted by the piston into compression above atmosphere. By so doing, the momentum of the air in the inlet pipe tends to add to the volume of the charge.† It may be noticed that where governing by volume throttling is used, the spring of the exhaust valve weakens; the increased suction of the piston on the intake stroke may cause exhaust gases to be drawn back through the valve into the cylinder, with the risk of a miss or a slow firing through the presence of exhaust gas round the sparking plug, or of premature ignition, if the gas is hot. The advantages of mechanical valves, therefore,

* Several new motors are now appearing, with mechanically operated valves.

† For automatic induction valves, very weak springs appear the best.

are sure and proper action,* which the trade is now beginning to appreciate.

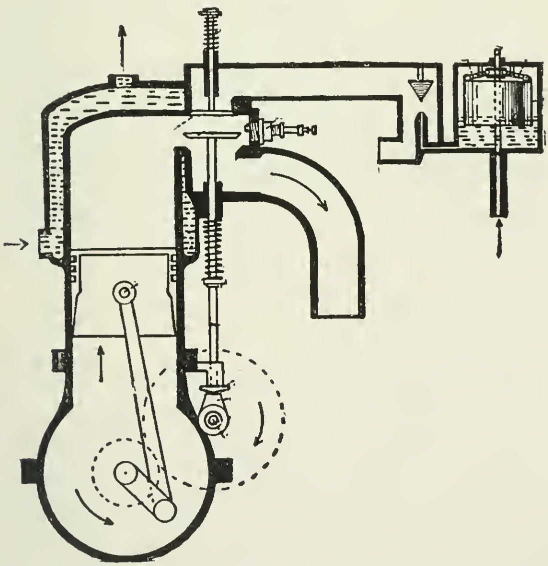
As regards the material for valves, their seating and fitting, there is again difference of opinion. There can be no question that the spindle and head are best made of different material. For the head the author favours nickel-steel; cast-iron wears well, but for small valves it seems hardly strong enough. A weak point in one-piece valves is the neck, and in this respect the exhaust valve and stem designed by Mr. W. Norris in 1892 is praiseworthy. Moreover it facilitates repairs, and the method of lift throws very little cross strain and irregular wear on the spindle. Where trouble has arisen, and there has been plenty of it, with burning, irregular wear, and breakage of valves, it has usually been ascribed to weakness in the neck, unsuitable material, faulty methods of lift, throttling of the exhaust by insufficient area of the valve, exhaust pipe, or silencer. Any deficiency here may lead to broken valves. With a choked exhaust, the pressure left in the cylinder combined with the spring may produce hammering of the valve on its seat. In time this leads to brittleness and fracture. There is, however, another cause of a very different nature, which the author suggests as a probable source of much of the irregular wear and ultimate fracture of valves. Those conversant with the construction of horizontal plunger pumps will recognise a defect frequently found in otherwise

* In "The Engineer," 20 July 1900, Mr. J. D. Roots thus discusses the lead that, to facilitate exhaust, should be given to the outlet valve: "The time of opening the valve should vary in accordance with the piston speed, and should open somewhat earlier, in the working stroke, the higher the speed, even though allowance be made, as it should be, in increased diameter of the valve for high speed .... (At) 750 revolutions per minute, the exhaust valve should begin to open when the piston has traversed four-fifths of the working stroke. Thus in an engine having a stroke of 5 inches, the exhaust valve should open at the commencement of the fifth inch of the stroke, remain open during the whole of the exhaust stroke, and close just after the dead point.... The exhaust valve in larger and heavier fixed engines of 200 revolutions per minute or less should open from $\frac{1}{7}$ to $\frac{1}{8}$ of the stroke, before the end of the working stroke." Timely opening of the exhaust reduces not only back-pressure, but also that on the rod and crank-pin, at a point where such pressure has least driving and most frictional and wearing effect.

well-designed machines. This is the placing of the valve seat on a level with the waterway. The effect of such an arrangement is that not only is the discharge greater on one side than on the other, but the water, diverted into a new direction, while in the act of passing the valve, exerts a tilting force on it, pressing the valve towards the waterway. The results are irregular wear, sticking, and hammering of the valve on its seat.

Now the usual disposition in the vertical motor is similar—a horizontal port with a vertical exhaust-valve, the latter seated on a level with the former. An analogous state of affairs is thus established, a flow of gas, in lieu of water, being diverted into a new direction while passing the valve. There is, therefore, the same unequal discharge, with the similar tilting action and tendency to force the valve from its true position. See Fig. 3.

Fig. 3.
Position of Motor Valves.



Showing the exhaust valve, so placed that the gases are diverted into a new direction while passing the valve; also that the discharge is greater on one than on the other side.

But there is this difference: in the pump the stroke is comparatively slow, the flow tardy, the pressure low, the valve, spindle, seat, and guides cold, and in the best condition to resist wear; whereas in the motor the valve beat is extremely rapid, the gas-flow swift, the pressure high, and all surfaces so highly heated as to be in the worst condition to withstand attrition and deformation. Thus the evils of bad design in the pump are much aggravated in the case of the motor, the tilting action being greater and the irregular burning and side wear more rapid.

The remedy in both cases is the same. The valve seats should be kept respectively below the waterway or the gas passage so as to permit the flow of water in the one case to rise upward until clear of the valve before taking a new direction, or the rush of gas in the other case to acquire a straight downward course before reaching the valve, Fig. 4. All tilting action is thus eliminated. Naturally the usual precaution of fully equal area in the annular space round the valve to that of the valve outlet must be preserved.

Far the better practice would be to avoid port passages and place the inlet and the outlet valves on the head of the combustion chamber.* With the heavier oils this position has the additional advantage of direct charge admission, without a possible condensation by contact with the port and cylinder walls. Naturally it slightly increases the height of the motor. Examples of valves so placed are the Buchet motors, the 3-cylinder 20-H.P. Maudslay motor, and the Belsize cars of Messrs. Marshall and Co.†

---

* To diminished heat loss, at the time of maximum temperature, by reduction of port surface, Mr. D. Clerk ascribes much of the high efficiency of the Barker Otto Cycle Gas-Engine. ("Recent Developments of Gas-Engines," 1895-6.)

† Combined with this position, as somewhat a novelty, though the idea has recurred in several previous patents, is the D'Equevilly valve, Fig. 5. It is set on the top of the compression space, and one port serves for exhaust and inlet. The exhaust valve is sufficiently large to form a seating for the inlet valve, which opens into the induction passage, the cold charge entering keeps the exhaust valve cool. Combination valves are a simplification, in one sense, but in other respects more difficult to manipulate.

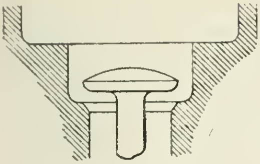


Fig. 4.
Method of Countersinking Valves to give direct flow.

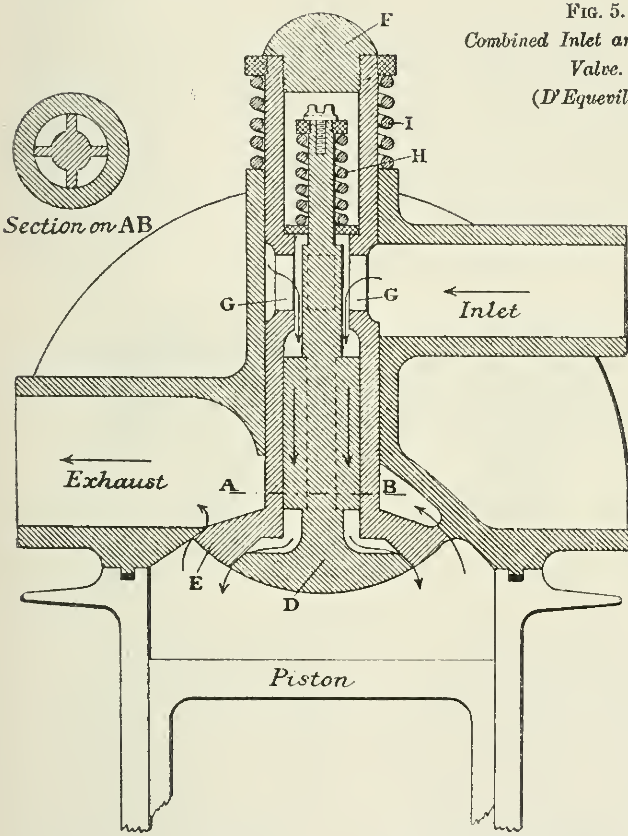
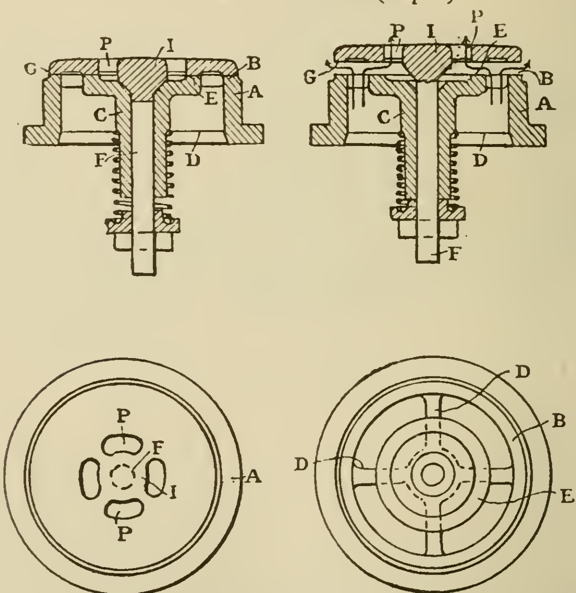


Fig. 5.
Combined Inlet and Exhaust Valve.
(D'Equevilly).

The exhaust valve E is recessed to receive the inlet valve D. F the cap of the exhaust valve spindle, is actuated by a two-to-one shaft and rod, not shown. I is the exhaust valve spring; H a weaker spring for the inlet. The shock of the exhaust spring valve closing bounces the inlet valve at the same moment. The inlet valve stem is fluted, as shown in section across A B, forming channels for the charge to the head of the valve.

Valve Area.—In this year's motors, there is among the best makers a marked and very praiseworthy tendency towards increased valve area. Where the sluggish-acting automatic inlet-valve is retained, the difficulty with high piston-speed of ensuring a full charge is increased; and, in such cases, if 80 feet per second for induction and 100 feet per second for exhaust are to be at all approximated, it is evident that the valve areas can scarcely be too ample. There is little doubt that the sharp blast considered necessary in the aspiration method of carburation to secure proper suction and mixing of the petrol has hitherto militated against the use of large-sized inlet pipe and valves. The necessity for this sharp blast is purely imaginary, as there are many very obvious ways in which the difficulties, real or apparent, are easily overcome.

Fig. 6.—*Annular Inlet Valve* (*Napier*).



A, cylindrical valve seat; B, E two annular flat face rings; D connecting radial webs. The ring E is formed in a sleeve C, forming bearing for valve spindle F. When the valve opens, the gas passes through the annular space between the seatings B E, and also through the space P, between the head I and the ring G, GE.

The tendency to enlarge valve areas became noticeable about the time of the late Paris Exhibition, and as further instance of its development may be mentioned the Napier so-called pyramidal or annular valve, Fig. 6. This valve claims, with the same lift, to give 50 per cent. larger passage than the ordinary mushroom type of the same diameter. The new "Centaure" motor of Messrs. Panhard and Levassor adopts a very similar triple-induction valve. So far as the author is aware, no clear rules for determining the valve areas of explosion engines have been published. There is no difficulty in calculating the induction-valve area, but the problem of the exhaust valve is less simple. In any case the common practice of making inlet and outlet valve of equal area cannot be right. In "The Engineer" of 20 July 1900, Mr. J. J. Roots gave certain formulæ for calculating valve areas.*

---

* Let A = area of cylinder in inches.

S = stroke in inches.

R = revolutions per minute.

e = area of exhaust valve in inches.

a = area of inlet valve in inches, when automatically opened.

m = " " " " " " " mechanically "

Then $e = \dfrac{A \times S \times R}{21360}$

$a = e \times 1{\cdot}18.$

$m = e \times 0{\cdot}75.$

Let d = the outside diameter of exhaust valve.

l = the lift of exhaust valve.

d_1 = the outside diameter of the inlet valve, mechanically opened.

l_1 = the lift of the inlet valve mechanically opened.

Then $l = \dfrac{d}{4{\cdot}1}$

$l_1 = \dfrac{d_1}{4{\cdot}8}$

The formulæ are applicable to engines up to 12 inches diameter and 20 inches stroke. The area of the valve for each formula is the area taken from the maximum diameter, or on the outside of the seating, the width of the seating being taken as one-ninth of the outside diameter in the larger engines, and relatively greater in the smaller and higher-speed motors. The ports to have not less than 25 per cent. greater area than the outside diameter of the valve seat.

These are the only formulæ the author remembers having seen, but they appear to be incomplete because they do not state what are the resulting velocities of the gas flow, and defective because they apparently assume discharge at equal pressure in all cases.

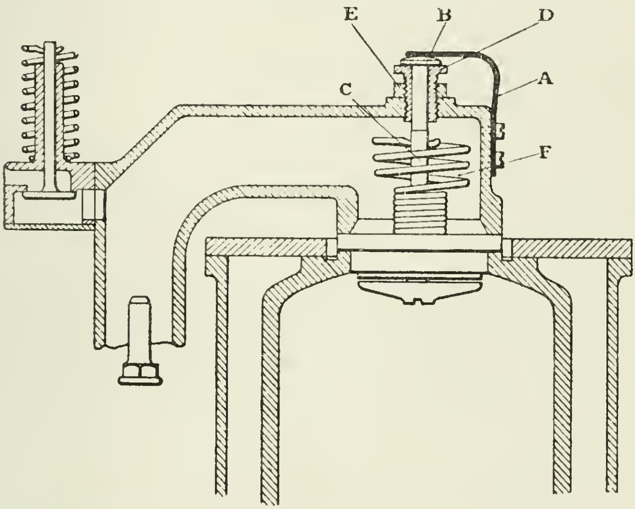
Accessibility of Valves.—In all the better classes of motors, this is now well provided for. In the Daimler, the removal of one nut enables the bridge to be removed and the valves inspected. Similar devices are now found on most cars.

Carburettors and Carburetting.—These are roughly divisible into two systems—aspiration carburettors, and positive-feed carburettors. Of the two, the latter, in the author's opinion, is unquestionably the better system. Most aspiration carburettors draw the petrol from a jet, communicating with a constant level chamber or reservoir. The result is inaccurate and faulty petrol supply, since the force of the suction varies with the speed of the engine. Rich charges are thus obtained when the engine is racing, and poor charges when it is slowed down from over-load, the reverse of what ought to be. Makers are now recognising this defect, and are introducing devices more or less closely approaching positive measurement. There is no need to describe these latter, because the type is well known in heavy oil-engine work, for instance the Crossley, the Weyman and Hitchcock, the Wells Bros., the Roots, and numbers of other patented devices. As instances of the introduction of positive fuel measurement in petrol motors may be cited the Koch pump, the Gobron-Brillié bucket measurer, the adjustable stop-jet in the Mercedes Simplex of the Cannstatt Daimler Company, a similar device in the De Dion voiturette carburettor, etc. In America quite a number of petrol motors use positive measurers, usually of the pump type; for instance the Webster, White and Middleton, New Era, Pierce, Springfield, etc.*

* At the last Paris Alcohol Motor Exhibition, Messrs. Ringelmann and Sorel, tracing defective diagrams to excess of air or of fuel, mention pumps with variable stroke, *i.e.*, positive measurers, as offering the best facility for perfect regulation.

There is a good deal of evidence to show that the problem of carburation is at present eliciting the attention of inventors—a sign that something yet better is wanted. To take one among many, Messrs. E. F. Bradly and W. R. Pidgeon have recently * published a new design of carburettor, Fig. 7. They found by experiment, as might have been surmised *a priori*, that, to get the maximum power

Fig. 7.—*Carburettor (Bradly-Pidgeon).*



A, recoil spring to induction valve; B induction valve steam head; C induction valve stem; D adjustable guide to valve stem; E lock-nut to D; F ordinary or main induction spring. Snifting valve shown to left.

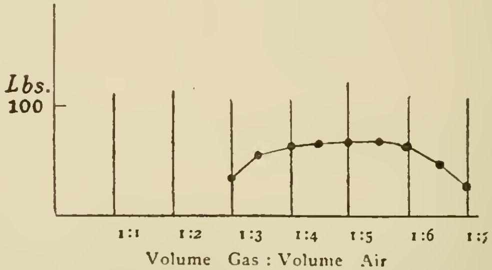
at any number of revolutions per minute, the jet of the carburettor must be larger for low speeds than for high ones, and, as it is difficult to adjust so small a thing as the hole in the jet, they insert a small air-spring valve in the air-pipe between the carburettor and the induction valve. This auxiliary valve opens wider and wider as the engine speed increases, closing again as it decreases, thus decreasing or increasing the suction on the jet. At starting, as the jet is a

* Motor Car Journal, 17 May 1902, page 236.

large one, the petrol supply is also large and the engine starts readily, then as it speeds up the air-valve comes into action, and automatically letting in more air reduces the mixture to and maintains it at the proper proportions. The idea of an auxiliary air-supply for this purpose is not new, and is found in the 8-H.P. De Dion light car, the Darracq light car, the American Holyoke tonneau, etc. In the motors of the Société des Automobiles Crouan, of Paris, the quantity and quality of the gas mixture is so automatically varied according to the speed of the engine that the force of the explosion increases as the speed diminishes; in other words, the greater force of the piston stroke tends to compensate for the loss in centrifugal power of the fly-wheel.

A number of recent devices on similar lines show that the tendency of the present motor is, and rightly so, towards discarding the crude action of the suction jet, pure and simple, in favour of positive measurers, preferably under control of the engine governor.*

* The value of positive measurement is shown in an article, communicated to "The Horseless Age," 28 May 1902, by C. E. Lucke, of the Columbia Laboratory, U.S.A. The curve of pressures for the possible explosive mixtures, vaporized kerosene and air, obtained in the engine, is given in the diagram below. This shows



that for the mixtures 3·5 to 1 up to 6:1, there is but little change in pressure, so that, judging from external indications, such as speed of an ungoverned engine or the brake load, the operator could not tell what mixture he was employing within these limits. It is plain, however, that in one case he would be using about twice as much fuel as in the other, though the effects on the engine would not appreciably differ. In other words, while many mixtures of kerosene, petrol, etc., will explode and the resultant pressure may not vary much, there is only one proportion that will do the most work with the least fuel.

In connection with carburation, the author raises the point whether it be better to carburate the incoming air, or to introduce the air first and then carburate it, that is, add the fuel, at the end of the compression-stroke. This latter method avoids all possibility of premature explosion, and thus enables higher compression to be used.* On the other hand, it is urged that the charge will be imperfectly mixed, and give imperfect and irregular combustion. The author is doubtful whether for petrol and gasoline there is anything in this objection, or whether, if there is anything, it is not more than discounted by the advantage to be gained. It is certain that a number of petrol motors run, and run successfully, by merely injecting the petrol into the cylinder and letting the air and heat do the rest. An instance is the American Weber gasoline motor. The petrol is drawn from a tank and supplied direct to the cylinder in a fluid state. No vaporiser is used, nor does the petrol come into contact with air until it reaches the combustion chamber. In the Otto gasoline motor, built by the American company of that name, no carburettor is used. The oil is pumped from an air-tight tank to a valve acted on by the governor. This admits a given quantity to the cylinder, when it is immediately pulverised by the incoming air and rendered explosive. No air reaches the petrol on its passage from the tank to the cylinder. In the German Lützky petrol motor of the Maschinen Gesellschaft, Nuremburg, the benzine is conveyed to the cylinder in a liquid state and vaporised per stroke as needed. In fact, in very many German petrol motors care is taken to exclude the air, until the oil reaches the cylinder. This is the case even where a separate vaporiser is used. Thus in the oil motor of Dopp Brothers, Berlin, each charge of oil is separately converted into vapour without any air, and highly superheated before it is admitted, in finely divided currents, to the combustion space, where it is mixed with air. Herr Dopp claims that this method

* With equal cylinder dimensions, it also supplies a denser charge. One drachm of petrol represents 1300 cubic inches of vapour. Consequently, by admitting petrol with air, the weight of the latter is proportionately reduced; while by drawing in air only, compressing, and then adding petrol, the charge weight and maximum pressure are correspondingly increased.

ensures regularity and completeness of combustion, low oil consumption, and quiet regular working without vibration. In the Russian Kablitz motor-car also, naphtha is injected into a red-hot vaporiser open to the cylinder, and immediately vaporised by the compressed air. Injection of the fuel at the end of compression is adopted in the Diesel motor, but in rather a different way and with a different object. On the whole, the author thinks that, for petrol at least, a good deal more stress is laid on pre-mixing than need be, and that carburation at the end of the stroke, inasmuch as it admits the use of higher compressions and has another important advantage, is probably as good if not better and more economical than the more ordinary method. It probably requires high compression.

The last point to be considered under the heading of carburetting is the use of heavy oils with higher flash-point, the usual household lighting oils. It would be, if not in the near future a requirement on the score of price, at least a convenience in this country if motors were adapted to use such oils as well as petrol; for the Indian trade it is a *sine quâ non*, since petrol cannot yet be obtained. This point has not been lost sight of, and quite a number of combination carburettors for the double purpose have lately appeared; but experience as to their efficiency is still wanting. With Russian oils there ought to be no difficulty, since these are sufficiently pure to require no more preparation than atomising and vaporization effected by an easy application of heat. Indeed it appears doubtful whether even vaporization is needed or mere spraying would not suffice. On this question the Specification No. 7538, 1895, of Mr. James Roots furnishes some information. It states: "I have found by experiment when oil is sprayed into a working cylinder that the essential thing is ignition, as the oil has not time to be and is not vaporised, but is fired as oil spray, and that once the ignition is commenced the flame passes almost as rapidly through the particles of oil, as oil spray, as through a completely vaporised and mixed charge of oil . . . "

It does not appear that Mr. Roots has since found reason to alter this statement. For Russian refined oils, therefore, a combination curburettor presents no great difficulties. With American oils it might not be so easy to get satisfactory results without special

vaporisers. These oils are "cut" differently, and contain waxy and resinous compounds that in long and continuous running would form deposits on the walls and valves. The conditions for successful use would appear to be: uniform delivery of minutely atomized oil in correct proportion, high cylinder temperature, no condensation by contact with cool surfaces, sufficient time for combustion. For alcohol, similar conditions, with higher compression, appear best suited.*

Fuel.—The consideration of the fuel used is a very important portion of the subject.

A very great deal has yet to be learned. It seems to the author astonishing that petrol should have been so long in use and yet so little known about it. He believes he is correct in stating that in this country at least neither the maximum explosion-pressures of various petrol mixtures, nor the times of attaining maximum pressure, nor the rates of cooling are yet ascertained. Under these circumstances makers, as far as carburation is concerned, must be working more or less in the dark.

A few years ago Dr. Boverton Redwood contributed some valuable information on the subject. The results of his experiments tabulated in "Transport of Petroleum" are as follows:—

"With seven volumes of the liquid (pentane and gasoline) to 100,000 volumes of air the combustion is a silent one, while with four times that proportion of liquid the mixture also burns without explosive violence. With between eight and nine volumes of liquid to 100,000 of air, there is a marked increase in the energy of the combustion, and, when the quantity of liquid is augmented to 10·5 volumes, a sharp explosion occurs. When the proportion of liquid is increased beyond about seventeen volumes, there is a perceptible decrease in the violence of the explosion, with corresponding gain in the volume and duration of the flame, and with twenty-one volumes of liquid to 100,000 of air the explosion is as mild as with 8·4 volumes."

* In the Wartburg lorry of the Fahrzeugfabrik, Eisenach, the motor is so constructed that the compression ratio can be changed from 1 to 4·4 for petrol, to 1 to 5·4 for alcohol.

These results, adequate for Dr. Redwood's purpose, are not sufficiently comprehensive for the requirements of the motor manufacturer. For his purpose, estimation of the value of any explosive mixture involves knowledge not only of the maximum explosion-pressure as one factor, but also of the rates of cooling as another factor. It is only from the faculty of producing pressure and the capacity of resisting cooling, that one arrives at the mean pressure which determines the true efficiency of the mixture. The determination of these factors is still wanting. It is, however, likely that the deficiency will soon be supplied, for the author is in a position to state that the necessary experiments are in progress. The results will be awaited with considerable interest, and there is little doubt that they will establish the value of petrol measuring devices for carburettors when efficiency and economy are rigorously followed.

But there is another phase of this problem requiring even closer research. Besides the determination of the fact that different petrol mixtures have certain rates of cooling, there is the ascertaining of the intrinsic reason, and why and wherefore of the facts, the relation of effect to cause, that is, the true knowledge or science of the problem. Attention is directed to this incomplete knowledge of the process of cooling, because it will be referred to again in connection with an interesting problem.

Under the head of fuel it may be noticed that the motor cars of today, more especially those of French makers, show a tendency to acquire greater range, that is, to be equally suited for the consumption of either petrol or alcohol. Is this a precursor of the supersession of the refined product of nature by the purely artificial production? That is a question for the chemists to decide.* There is, however, an interesting phenomenon which the trial of alcohol has made sufficiently prominent to merit attention. The point is clearly put in an article in "Engineering," 10 January 1902, on "French Spirit Motors": "In theory, the consumption of spirits for an

* The progress made, in Germany, in the alcohol industry appears from official statistics, showing that, in 1901, 30,624,000 gallons of denaturised alcohol were used for technical purposes—motors, stoves, lamps, etc.

equal power is 1·8 times the consumption of petrol; in practice, however, the presence of water in the spirits increases the elasticity and efficiency of the power, and the proportion is only as 1·25 to 1. ...Spirit motors have more elasticity than petroleum motors and work more softly; the pressure of the explosion can be increased without disadvantage to the machine, the expansion-curve being very regular.... It has been asserted, from results of tests carried out in Germany, that the efficiency of spirit motors is 23 per cent., against 15 per cent. for petroleum, and 13 per cent. for steam-engines."

Why should the presence of water in the alcohol motor give this increased efficiency? Before attempting a reply, it may be stated that the same phenomenon has been observed in the petrol motor; for, if the published reports (Zeitschrift des Vereins deutscher Ingenieure, Bd. xxxxiv, 1900) are to be credited, the addition of water to the charge in the Banki engine reduced the consumption to 0·45 pints per B.H.P. per hour.* There again, in general terms, the advantages claimed were greater economy, greater elasticity, and smoother running.

In July of this year, Mr. C. Rainey, at the author's request, made some experiments with water injection in a petrol motor. Owing to want of appliances no very close work could be done, but the general results reported by Mr. Rainey are these:—

1. That while maintaining the petrol supply constant, the addition of water gave increase of power and cooler running.

2. That this effect was maintained until the water reached a quantity equal to the amount of petrol.

3. That a larger quantity of water interfered with the sparking, and caused frequent failures of ignition, which after a short time failed altogether.

---

* The consumption appears to be even lower, for on 16 July 1902, Professor Banki wrote to the author: "Der Brennstoff-verbrauch ist bei den neuerer Ausführungen noch etwas günstiger als bei den Versuchen von Prof. Meyer und von den Herren O. Taborsky und E. Jónás gefunden wurde. So hat ein 16-H.P. Motor nur 0·205–0·210 kgr. Verbrauch. Ausser mit Benzin (bis 0·75 specifisches Gewicht) werden meine Motore auch für Spiritus und Gasbetrieb bei gleichem wirtschaftlichen Effect ausgeführt...."

As far as the author is aware, no very complete explanation of these better results has so far been published. The advantages of water have been described as a contribution of mechanical energy in the form of steam,* as a cooling agent obtaining increased charge volume and higher compression,† as an absorber of the violence of explosion, etc. To these explanations the author will add another. During the recent testing with tube ignition of a petrol motor, in which the cylinder wall developed porosity, admitting moisture to the combustion chamber, a sudden advance in ignition was observed, together with an increase of exhaust temperature, leading to burning of the valves. The author considered the following to be the possible reason: Assuming the cylinder charge to be pentane, C_5H_{12}, the addition of water or aqueous vapour in contact with the incandescent tube might lead to partial decomposition, carbon combining to carbon monoxide, hydrogen being liberated.‡ In other words, water-gas would be formed. The advance in ignition would be due to the greater inflammability of the gas, and may be illustrated thus: The molecular weight of pentane being 72, 256 of oxygen would be required for its perfect combustion. On the other hand, the molecular weight of the water-gas, $CO + H_4$, being 32, the oxygen needed for complete combustion would be 48. One part by weight of pentane, therefore, would require $3 \cdot 5$ O, and one part of water-gas $1 \cdot 5$ O. This at once shows why the ignition is advanced, the greater inflammability of the water-gas being due to the lesser amount of oxygen wanted for combustion. The increased temperature of exhaust might be accounted for by assuming that the nascent

---

* Patent No. $20703\frac{25}{}$ F. Lister, No. $23270\frac{26}{}$ E. Petréano. (The specification is interesting because it gives a diagram showing increased power.)

† Patents No. $15109\frac{24}{}$ G. Schimmung. "In all gas-engines," says the specification, "the fall of temperature actually utilized is from 2000° C. to 800° or 600° C., whereas by the expansion of the gases and combustion products generated through the water injection the fall of temperature available for useful work is from 2000° C. to about 40° C.—No. $12306\frac{25}{}$ R. Diesel.—Reduction of the volume of the compressed air, and therefore heavier charge, by injection of water spray.—No. $5147\frac{27}{}$ S. Rolfe, etc.

‡ Partial dissociation of aqueous vapour, by sudden vaporization, in the cylinder, is referred to in Patent No. $23270\frac{26}{}$ E. Petréano.

water-gas, burnt with a fierce heat and acting as an extended flame carrier, produced more rapid and complete combustion of the charge. Unfortunately the testing department in question is entirely destitute of any laboratory or appliances for following up questions of research, and the author was unable to analyse the exhaust gases, and thus determine whether the hypothesis of more complete combustion was correct. The above is not an isolated case, nor is it confined to one size or type of motor nor to tube ignition only, the same facts being observed when electric ignition is in use. It has been suggested that earlier ignition is due to the explosion gas entering the water-jacket, and, by driving the water from the cylinder walls, increasing the heat of the combustion chamber. But there are a number of arguments against this suggestion, and the phenomena of earlier ignition and hotter exhaust when a little water is present, with increase of power and cooler running when a large and regular supply is added, need another explanation.

Treated mathematically, as a purely thermal problem of profit and loss, it can, no doubt, be shown that, whatever be the physical condition of the water at the beginning of the compression stroke, and whatever be the laws of specific heat, the addition of water to the charge is an entry on the wrong side of the balance sheet of an explosion motor; and that the advantage of water injection can lie only in the possibility it gives,—of employing much higher compression without risk of premature ignition,—of obtaining heavier charges,—and of reducing heat loss through the cylinder walls. But does this academical statement meet the whole case? Does it explain the phenomena above? Does it satisfactorily explain the increase of power, without the increase of compression, to which Professor Meyer attributes the results of the Banki motor? And does it explain the remarkably high and maintained mean pressure of that engine when water is used?

Several arguments might be advanced for the entry of an additional factor into the problem, the possible improvement of combustion by the presence of water vapour. The idea is not new. Proposals to improve combustion by decomposing the fuel with steam or aqueous vapour occur in many patents, for example No. 14242

of '95 J. K. Ladd, and No. 10018 of '96 H. Lane.* Fritz Altmann's patent No. 29858 of '96 is for the production of a hot, blue, smokeless flame from hydrocarbons by evaporating together with the burning liquid a certain percentage of water. "Thus is produced a hot, blue, and absolutely smokeless flame . . . suitable for the ignition of the combustible charges in gas and like motor engines." * The more perfect combustion by simultaneously and together evaporating water and vaporizing oil is ascribed by Altmann to an oxidizing action of the water vapour. Under the influences of high temperature, the close contact of compression, with the physical and chemical disturbances of explosion, it does not seem impossible that water vapour may cease to be inert, and, under certain conditions, may promote the splitting of a hydrocarbon into light gases, olefines, hydrogen, burning at lower temperatures (1124° F.), and into heavier residues, carbon monoxide, etc., requiring a higher temperature (1200°–1350° F.), for their combination with oxygen. It would be to the presence of these light gases that earlier ignition might be due, while the hotter exhaust might be attributable to the later, and probably better, combustion of the heavier products, by reason of the rapid and extended initial inflammation. Communicating with the author on this question, Mr. H. J. Bult, F.C.S., wrote: "The decomposition of petrol in the presence of water might take the form you suggest, and could be explained by the equation: C_5H_{12} (pentane) $+ H_2O = C_2H_6$ (ethane) $+ CO + C_2H_4$ (ethylene) $+ 2\ H_2$. But he expressed an opinion that the reaction might rather be more in accordance with $C_5H_{12} + H_2O = C_4H_{10} + CO + 2\ H_2$."

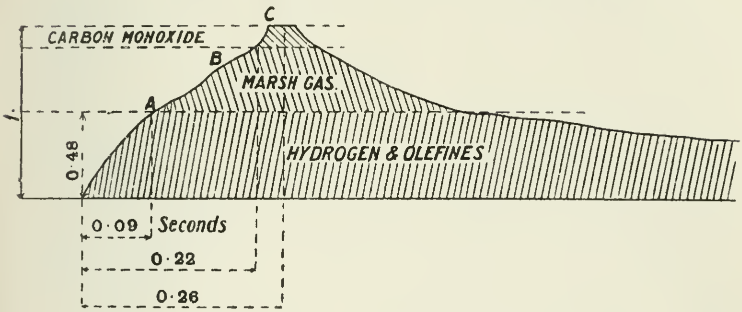
Another reason for attributing the phenomena possibly to decomposition is, as Mr. Bult proceeded to add, that it is well known, when petroleum compounds, especially those belonging to the paraffin series, are superheated, they partially decompose into olefines and gases, at the same time leaving a deposit of carbon. This is shown by the equation: C_7H_{16} (heptane) $= C_4H_{10}$ (tetrane)

---

* *See* Appendix I (page 744).

Fig. 8.

Diagram showing characteristic feature of all Coal-gas explosions.



$+ C_2H_4$ (ethylene) $+ H_2 + C$, or $C_5H_{12} = C_4H_8 + C + 2H_2$. The author's suggestion, therefore, is that the presence of water vapour, at a certain temperature, may disturb the chemical equilibrium of the oil at the critical point, hastening and promoting its decomposition. That a hydrocarbon, even without the presence of water, would in the combustion chamber decompose into light and heavy constituents, seems very probable—the result being combustion and heat evolution more or less of an irregularly progressive nature. An interesting diagram, Fig. 8, illustrating such action in a coal-gas mixture, is given in Mr. Grover's treatise on "Modern Gas and Oil Engines."*

The diagram represents the explosion of 1 volume of coal-gas with 12 volumes of air. Out of the 20,162 thermal units in 1 lb. of coal-gas,

* "It is found, from an examination of the diagrams taken during the explosions of pure mixtures of air and coal-gas, that the first alteration in the slope of the rising pressure-curve occurs at 0·4 of the maximum height of the diagram. Whatever may be the real cause of this characteristic of all coal-gas explosion diagrams, it is interesting to note that the heat generated by the combustion of the hydrogen and the olefines combined is found to be just 0·4 of the total heat of the whole of the constituents of the coal-gas experimented upon."—*Ibid*, 3rd edition, page 228.

Mr. Grover calculates that 0·417 of the total is due to the hydrogen and olefines. Assuming, therefore, that decomposition of the mixture takes place, and that the resulting hydrogen and olefines are first ignited, leaving the marsh-gas and carbon monoxide to inflame later, the pressure-curve ought to show its first alteration at 0·417 of its maximum height. It will be seen that this is practically the case, thus proving decomposition and progressive burning in the case of the coal-gas mixture.

With the object of studying the problem of combustion in oil engines, the author compiled Tables 1 and 2 (page 699).

Diagrams for Nos. 1–12 are published in Mr. Dugald Clerk's work, "The Gas and Oil Engine," the rest were supplied by the makers. The fuel in the case of the gas engines was coal-gas, that in the oil motors was Royal Daylight.

Comparing the oil- with the gas-engines, using similar compressions, it will be noticed that the ratios of maximum pressure to compression in the oil motors are, if anything, higher than those in the gas-engines; while the ratios of mean pressure to maximum pressure are much lower. May it not be legitimate to attribute the high initial pressures of the oil motor to the rapid inflammation of volatile gases, and the low mean pressures to the slower and imperfect combustion of the residual products of the decomposition. With the data of their 7 B.H.P. oil engine, Messrs. Tangyes supplied the following diagram, Fig. 9 (page 700).

This diagram shows very distinctly sudden and high explosion of volatile gases, succeeded by gradual combustion of slower burning products. There is, therefore, evidence for the decomposition of hydrocarbon charges by cylinder temperature, and further for the promotion and perhaps modification of that decomposition, by the presence of a small percentage of water vapour. The addition of a considerable proportion of water naturally and obviously conduces to cooler running, but it is not clear whether these larger proportions aid, impede, or prevent the decomposition of the hydrocarbon. They do, however, increase power.* The most recent converts to

* *See* Appendix I (page 744).

TABLE 1.—*Gas Engines.*

No.	Description of Engine.	Compression in lbs.	Maximum Pressure in lbs.	Ratio of Maximum Pressure to Compression.	Mean Pressure in lbs.	Ratio of Mean to Maximum Pressure.	Ratio of Mean Pressure to Compression.
1	4 N.H.P. Crossley.	87·5	275	3·1 to 1	100	·36	1·1 to 1
2	6 ,, ,,	31	126	4·0 to 1	57	·45	1·8 to 1
3	9 ,, ,,	38	133	3·5 to 1	58·4	·44	1·5 to 1
4	9 ,, ,,	48	200	4·1 to 1	81·5	·40	1·7 to 1
5	30 ,, ,,	75	318	4·2 to 1	113·5	·35	1·5 to 1
6	9 ,, Stockport.	60	244	4·0 to 1			
7	9 ,, ,,	90	272	3·0 to 1			
8	9 ,, Barker.	50	195	3·9 to 1	67	·34	1·3 to 1
9	12 ,, ,,	55	244	4·4 to 1	76	·31	1·4 to 1
10	12 ,, ,,	51	250	4·9 to 1	76	·30	1·5 to 1
11	35 ,, Tangyes.	73	220	3·0 to 1	89	·40	1·2 to 1

TABLE 2.—*Oil Engines.*

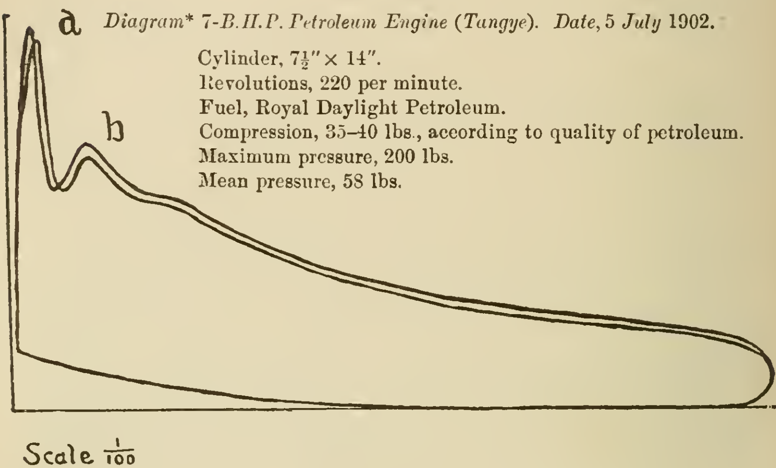
No.	Description of Engine.	Compression in lbs.	Maximum Pressure in lbs.	Ratio of Maximum Pressure to Compression.	Mean Pressure in lbs.	Ratio of Mean to Maximum Pressure.	Ratio of Mean Pressure to Compression.
12	7 N.H.P. Crossley.	80	240	3·0 to 1	64	·26	0·8 to 1
13	8 ,, ,,	50	240	4·8 to 1	54	·22	1·08 to 1
14	4 ,, ,,						
15	7 ,, ,,	45	210	4·6 to 1	65	·31	1·4 to 1
16	10 ,, ,,						
17	10 ,, ,,	67	250	3·7 to 1	62	·25	0·92 to 1
18	7 ,, Tangyes.	40 mean.	200	5·0 to 1	58	·29	1·4 to 1

Grouping and comparing Nos. 14, 15, 16, 18 with No. 4, the oil engines, with an average 4 lbs. lower compression, give 7 lbs. higher maximum pressure, but 18 lbs. lower mean pressure; or taking No. 17 with No. 11, the oil engine, with 6 lbs. lower compression, gives 30 lbs. higher maximum pressure, but 27 lbs. lower mean pressure.

water injection appear to be Messrs. Priestman Brothers; and the latest patents for the use of water in an explosion engine are No. 10449^{02} Weyland, and No. 704,995^{02} (U.S.A.) C. W. Weiss.

There are, however, strange things in nature, and it is quite possible that a very different explanation may be the right one.

Fig. 9.



It is claimed that the addition of either hot or cold air to steam serves to lower the point of condensation. In Lindley's patent, No. 24,949 of 1894, this is fully described, and is utilized to cover the use of steam, working expansively, considerably beyond the point where steam alone, at the same temperature, would have become condensed. The explanation offered is in accordance with the rule that generally, if two fluids with different boiling points are mixed, the boiling point of the mixture is intermediate between that of the components.

* Regarding this diagram, Messrs. Tangyes write: "The diagram sent is similar to that obtained from any size of our engines, and the information given *re* pressures, etc., will apply to all sizes. The spring of the indicator is not at fault in regard to the initial pressure. A similar diagram would be obtained even with a much stronger spring." (15 July 1902.)

Thus the boiling point of air being more than 200° F. below zero, a comparatively small proportion of air mixed with steam, reduces very materially the temperature at which condensation takes place. It is further stated that, by raising the air to an equality of pressure with the steam, the temperature of the air may be increased by the development of the latent heat therein, so as to exceed the temperature of the steam. Thus the temperature of the whole is raised and practically the steam is superheated. Now, is it possible that some analogous action takes place when water vapour is mixed with the explosion gases? Is there a development of latent heat? Is there a marked retardation in the rate of cooling, and therefore a higher exhaust temperature? Is there a retarding effect on dissociation and so the attainment of a higher initial temperature; or is there an acceleration in recombination after dissociation, and so the maintenance of a higher mean temperature? Who knows? But as Mr. Clerk puts it, without exception the actual pressure of explosion falls far short of the calculated pressure; in some manner the heat is suppressed or lost; for some reason nearly one-half of the heat present, as inflammable gas, in any explosive mixture, true or dilute, is kept back and prevented from causing the increase of pressure to be expected from it. There is, therefore, a very wide margin for greater initial heat development, and it may be that the presence of water vapour, true or decomposed, has some developing action on this latent potentiality. The whole question is obscure, and automobilists must not conceive the idea that even if water is proved to be a useful addition to the charge, the problem is at once solved. Probably correct employment of water will demand certain conditions that have yet to be studied and may require a change in the motor design. Anticipating the objection likely to be raised, that water will corrode the valves and cylinder, the author replies that this does not appear to be the case. With alcohol, containing water, it has been found that where the curve of the motor was regular, indicating perfect combustion, the condensation liquid of the exhaust was neutral and there was no attack of the valves and cylinder walls. Three years of experience with the Banki oil and benzine motors show no corrosion from the use of

water.* Nor is it likely that so experienced a firm as Messrs. Priestman Brothers would have adopted water-injection, if corrosion was to be feared.

In another direction also, and this time with more definite knowledge and purpose, improvements in fuel are under consideration. These lie in chemical additions of explosive nature as petrol enrichers. The idea is not new and frequently recurs in past patents. There is no theoretical difficulty in chemically increasing the explosive power of petrol. But there are difficulties of a practical character which consists in finding an enricher that fulfils the two conditions—of not increasing the cost of the fuel per horse-power; and of not introducing any element of danger in its use.

Picric acid has been experimented with, but it is manifestly dangerous to handle, and is said to leave a highly explosive deposit in the exhaust pipe and silencer. Bisulphide of carbon has been frequently suggested; but it will certainly need to be deodorised. Curiously enough salt also has been recommended. The effect of this ingredient, if any, would be due to the formation of chloride of nitrogen and hydrochloric acid, quite prohibiting its use. There are, however, other possible means of enriching petrol; and the author, in conjunction with Mr. H. J. Bult is now considering one of a promising nature.

Among the fads relating to fuel improvements may be mentioned various proposals for increasing oxygen in the air charge. In Patent No. 6573[96] H. J. Dowsing describes an ozonizing apparatus,

---

* Extract of a letter, Budapest, 16 July 1902, from Professor Banki to the author: "Diese Motore werden von der Firma Ganz und Co., Budapest, seit beiläufig 3 Jahre fabricirt, und sind seit dieser Zeit eine grössere Anzahl verschiedener Grösser (von 5 H.P. bis 40 H.P.) im Betriebe. Es liegt also eine Praxis von 3 Jahre vor, welcher zeigt dass die Wassereinspritzung und die damit verbundene hohe Span für die Dauerhaftigkeit der Motore unschädlich ist. Es laufen nämlich Motore in ununterbrochenem Betriebe seit dieser Zeit ohne jeder Reparatur und ohne, dass Ventile und Cylinder merkbar gelitten hätten. Nur bei einigen Anlagen haben sich infolge schlechten saüerehaltigen Wassers Defecte gezeigt, wo wir aber durch Beimischung von Soda dem Übelstande abgeholfen haben."

while a paragraph lately published * states that Professor Carl Linde suggests the employment of liquid air instead of drawing in ordinary atmospheric air, considering this would possibly render cooling water superfluous and materially increasing the motor output, as the air would be got in a highly-condensed form, and owing to the cooling effect a much higher compression could be used, thus increasing efficiency as well as output. The suggestion is ingenious, but scarcely practical.

Ignition.—Next to the formation and constitution of the charge come the methods of its ignition.

Lamp ignition, except as a standby, may be said to have disappeared.

A little while ago some interest was excited by a new catalytic ignition. Such a method, however, has neither the flexibility, the inflammation capacity, the certainty, nor the suitability of properly designed electric firing. When it is recalled that incandescence is dependent on the concurrence of several factors into which the charge composition and governing of the motor enter, and that retardation and advancement of ignition are not nearly so perfectly controlled, as with the electric current, enough has been said to indicate the weakness of this system.

The only method, therefore, to be considered in detail is the electric. This divides itself into dynamo, accumulators,† magneto-electric,‡ or combinations. The dynamo is rarely used alone; more generally it serves to ignite the charge, while the surplus current goes to the accumulators, which are thus kept ready for emergency or for lighting purposes. This seems an excellent if not the best system. As regards accumulators, the author's experience is that they never run nearly the mileage claimed and are otherwise

* "Automotor Journal," 24 May 1902, page 139.

† In America, dry batteries, on account of greater lightness per unit of electrical capacity, compactness and dryness, are preferred. Such batteries, however, are more liable to electrical leakage and are not rechargeable.

‡ The majority of continental large gas-engines use magneto low-tension spark ignition.

troublesome. In this country, the best known magneto ignition is the Simms-Bosch. The Canstatt German Daimler Co. are said to have found the Bergmann Rotary Magneto-Electric apparatus very satisfactory. This produces alternating currents of low tension, and thus easy insulation; while the only moving part is the rotary armature. The magnets may be run at the same speed as the engine, and at very low speeds produce sparks of sufficient intensity. A method of low tension ignition, devised by Professor Burstall and fully described in the Proceedings of the Gas-Engine Research Committee,* has an excellent record in stationary work. Professor Kennedy, Chairman of the Committee, and Professor Burstall kindly gave the author permission to test its value for petrol-car motors; but the author could not persuade the manufacturers with whom he was in communication to take any interest in the matter, and cannot therefore state whether the apparatus would be equally successful for automobiles. In any case, as the invention of a clever scientist, a trial should prove instructive. So far the best induction coils are made in France.

In whatever form it is applied, electric ignition is a notable advance over previous methods. It provides absolute immunity against fire; it furnishes a spark well suited to explosive mixtures, it increases efficiency by enabling the charge to be fired at the moment of maximum compression, and it admits of the employment of higher compressions.

Existing systems of electric ignition admit, among other directions, of improvement on two lines—automatic timing and automatic consumption of current. The timing of the spark should automatically adjust itself to the speed of the engine. To illustrate this by an extreme case, assume a motor running at high speed and the spark set to pass at the moments of maximum compression; if suddenly, by the application of the throttle or other cause, the speed is greatly reduced, premature ignition will result, with considerable shock to the engine, crank-pin and bearings. But between this danger point and the period of correct firing is a gamut of speed variations, in all of which to maintain correct periodicity the timing

* Proceedings 1901, page 1032.

of the spark should be altered. To repeat this in other words—for the matter is more important than many makers seem to think—with early ignition there is injurious strain on the engine, probable heating of the crank-pin, and undue wear on the crank-shaft bearings. With late ignition there is considerable loss of power, high exhaust pressure with increased strain on the exhaust valve gear, incomplete combustion, sufficiently prolonged, perhaps, to cause gradually burning of the valves, and possibly back-firing of the fresh charge. With regard to the period of normal ignition, the author's own view is that it might be well so to dimension the compression chamber and stroke as to produce at the dead points slightly more compression than it is intended to use for explosion, thus allowing the crank to pass the dead point and gather way before igniting the mixture at the working compression point. On the indicator diagram, the explosion line, instead of being vertical, would then slightly incline towards the expansion-curve. In any case efficient running greatly depends on accurate ignition, and should be treated accordingly. At present, timing is mostly left to hand regulation by the driver * ; but attention is now being given to automatic spark controllers, one of which is illustrated, Fig. 10 (page 706). † A somewhat simpler device, designed by the author, will presently be noticed.

A second line for improvement is automatic regulation of the amount of current used. Naturally this is of chief importance where accumulators only are used. At present the flow of current is usually made by a brush brought in touch with a contact piece on

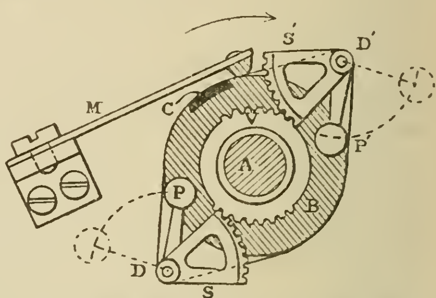
---

* Of Messrs. G. F. Milnes' new 20-H.P. car, "The Automotor Journal" (9 August 1902) writes :—"The time of ignition is not variable by the driver, and the only way in which an earlier ignition of the charge accompanies an increase in engine speed is in so far as the increase in the engine speed affects the quantity of current generated by the magneto, and, therefore, the intensity of the spark in the combustion chamber." In a lecture (23 April), before the Long Island Automobile Club, Mr. Hiram P. Maxim suggested the use of this principle for motors of moderate speed. In the Apple magneto, the spark is timed by the compression.

† Another arrangement is described in patent No. 17,221$\frac{96}{}$, C. Gautier and Wehrlé.

a rotary disc. If this contact piece is made of sufficient width to ensure the passage of enough current when the motor is running at high speed, it will pass more than sufficient current when the engine speed is reduced. To obtain automatic regulation of the current consumed, and of the time of sparking, the author has suggested using wedge-shaped contact pieces on the rotating disc, and allowing the disc under the direction of a governor an in-and-out movement on the shaft, Fig. 11. The action would be as

Fig. 10.
Automatic Spark Controller.



The fibre contact-breaker disc is mounted on a sleeve V, rotatable round the motor shaft A. As the speed accelerates, the centrifugal masses P P′, pivoted on studs D D', are forced outwards, causing partial rotation of the toothed sectors S S′. The motion of the sectors by means of the sleeve V, loose on the shaft A, advances the position of the disc, so that the brush M establishes earlier touch with the contact plate C.

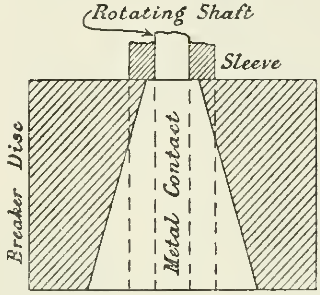
follows:—As the motor speed increased, the disc would slide, say backwards, bringing the wider portion of the contact pieces under the brush; as the speed decreased the reverse would take place. This would give increased contact surface and earlier firing for high speeds with lessened surface and later ignition for slower speeds, that is, automatic regulation of current and sparking period.

Systems of Governing.—Governing is so intimately connected with valve action, charge formation, and ignition, that it may well be considered next. For the purposes of governing, the old "hit-and-miss," or total cut-out arrangement, has practically disappeared. In its place, four systems are in use.

By far the larger number of car motors use a charge volume throttle, Fig. 12 (page 708), usually a valve fixed on the induction pipe, but occasionally, as in the Bollée and Duryea cars, in the form of an inlet valve with variable lift. The throttle, worked by hand, or by the governor, or by both, reduces the volume of the charge admitted and

Fig. 11.

Contact Breaker (author's), for obtaining automatic regulation of timing and current consumption.



thus slows down the motor. The author has no hesitation in condemning this system as theoretically bad. Incomplete filling of the cylinder reduces the compression, and thus renders the conditions for efficient and economical explosion less favourable. Again, the induction of the charge below atmospheric pressure entails negative work.* Thirdly, where jet carburation is used, the mixture is varied.

The second system, less general, is the exhaust throttle. The opening of the exhaust valve is retarded, a certain proportion of exhaust gas remains in the cylinder, the inlet valve opens later, and less fresh charge is admitted. In this case, there is a certain amount of back pressure, and the mixture is diluted † with exhaust gases ; but

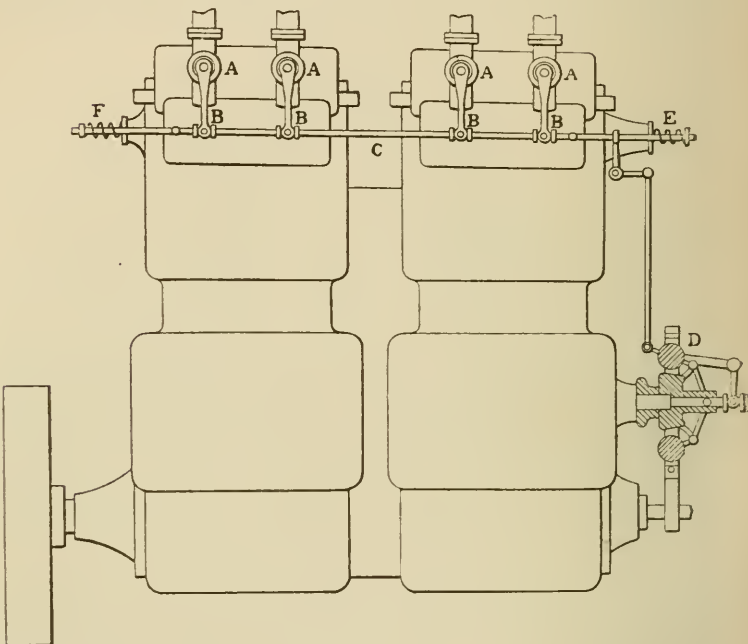
* Often 7 or 8 per cent. of the indicated horse-power.

† Probably by stratification rather than mixing. "According to a well-known physical phenomenon, a fresh mixture of air and petroleum, or other gases, mixes with burnt gas only with difficulty." Patent No. 9052$\frac{26}{}$, A. A. Loyal. "It is probable that coal gas and air are more intimately mixed with one another than with the residual gases." "Modern Gas and Oil Engines," F. G. Grover, 3rd edition, page 222.

the cylinder being fully filled, the compression is preserved, and there is sufficient evidence to show that from this factor alone greater economy results. The marked economy of the Gillet-Forest motor

Fig. 12.

System of Volume Throttling (Mors).



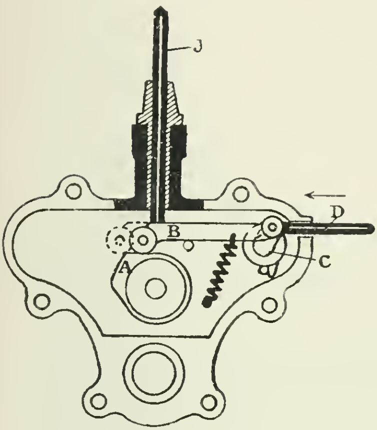
AA throttle valves on induction pipes; BB valve levers, C valve shaft, operating under the action of the governor D. Of the two springs E and F, the former is the stronger, and tends to open the valves. By the use of these springs, the valve action is more sensitive than when the governor alone is used.

is attributed to this method oi governing. An illustration of the application of the principle is the De Dion Patent, No. 22762 of 1900, Fig. 13. Where this method of governing is adopted,

correctness of mixture would appear very necessary. For, assuming Mr. Grover's experiments with coal gas, as applicable to hydrocarbons, the mean pressure is influenced not by the products of combustion present, within the workable limits, but by the correct ratio of air to gas, which alone determines the possibility of an explosion and the pressure generated.*

Fig. 13.

Exhaust Governor (De Dion and Bouton).



A, cam acting, through lever B, on exhaust valve stem tappet J. B lever pivoted to crank C, and movable from right to left, by rod D. Any movement of the lever to the left decreases the lift of the valve, as may be seen from the dotted or maximum position of the lever, at which position the exhaust valve remains closed.

A third system, in very general use, usually in combination with one of the preceding methods, is by retarding the charge ignition. The effect of delayed ignition is to give the piston time to expand the charge, thus reducing the force of the explosion and the duration of its action on the piston. In other words, the full power value of the oil is not obtained. The method is, therefore, wasteful, and unless automatically coupled with the throttle valve, may, in the hands of a careless driver, lead to premature explosion.

The author inclines to think that the second, or perhaps a fourth, method would be the best, namely governing by retaining

* "Modern Gas and Oil Engines," F. G. Grover, 3rd edition, pages 225–226.

the full charge of air, and reducing the amount of petrol.* The methods of carburation in the De Dion, Darracq, and Holyoke cars, already mentioned, are on these lines. It might be thought that governing on this plan could not be extended over more than a fifty per cent. variation of speed, the "critical point" of the mixture being then reached. With the ordinary methods of carburation this would probably be the case. But by carburating at or near the end of the compression stroke, it is likely that a far wider range might be covered. The difficulty of ignition could be met by setting the ignition-plug in the course of the incoming fuel, thus ensuring locally a mixture, sufficiently rich for inflammation. A provision of this kind is described, among others, in Patent No. 3971, 1893, of Messrs. Hartley and Kerr. Supercompression, for the same purpose, is described in Patent No. 13,325$\frac{97}{}$, L. A. Letourbe, who condemns volume throttling on account of its thermal inefficiency.

Charge Expansion.—Having carried the subject as far as the ignition of the charge, there remain a few other points on which it may be wise to add a word or two before describing the application of the motor power to the car itself.

The first of these points is expansion during the working stroke. As a direct object of design, no Otto cycle petrol-car motor on the market provides for increased expansion during the working stroke; indirectly, as a result of governing by throttling, greater expansion, under the action of the throttling, is obtained. The disadvantages of this method have already been noticed; loss of fuel value by reduced compression,† negative work in suction below atmosphere

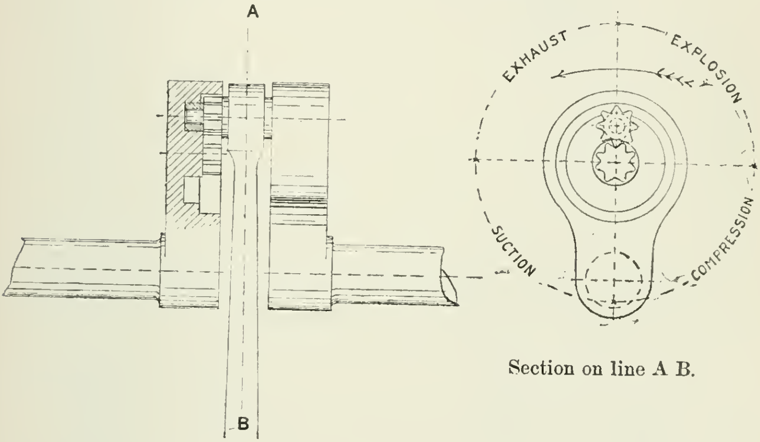
---

* In the 1,200-H.P. 4-cylinder Otto gas-engine, at the Hoerde Ironworks, Westphalia, governing is on this plan. The air admitted is practically constant, but the moment of opening the gas-valve is varied. When this opens, the usual mixture flows in. The 500-H.P. two-cycle double-acting Körting engine also is governed on this method. The full amount of air is supplied, but the point of gas inflow is made later and later. In both cases, fresh mixture is retained near the inlet valve and there fired.

† To maintain compression with reduced charge volume, many inventors have recourse to movable compression plates, e.g., Patents, No. 5681$\frac{94}{}$, P. Mitchelmore; No. 6972$\frac{95}{}$, W. Donaldson; No. 22690$\frac{95}{}$, G. Cummings; No. 26,638$\frac{96}{}$, R. W. Allsop, &c.

pressure; and, if gain by increased expansion were in view, reduced power by the diminished weight of charge. Though it is doubtful whether in Otto cycle car-motors any attempt at further utilization of the exhaust pressure would be successful, efforts in this direction are worth consideration. To overcome the disadvantages enumerated above, some inventors admitted a full charge to the cylinder, subsequently expelling a portion, thus giving greater expansion to the rest. Two variations may be noticed. In their patent, No. 8469 of 1891, the Gas Motoren Fabrik Deutz draw

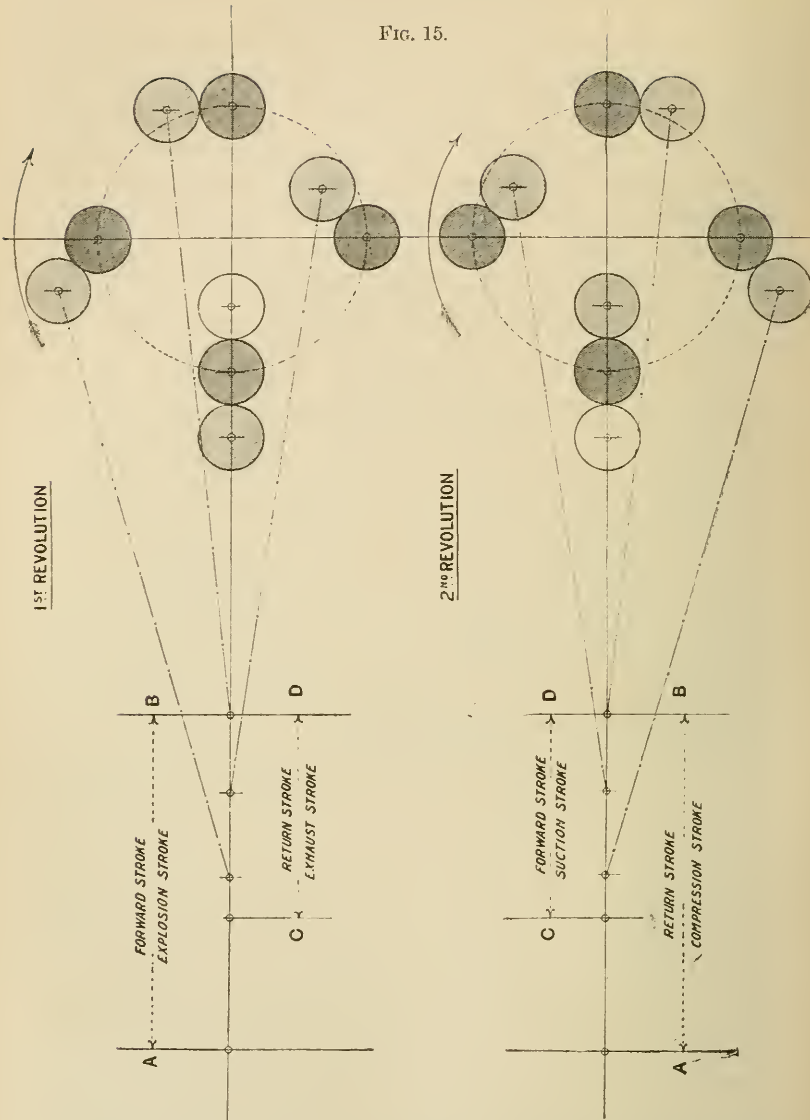
Fig. 14.
Increased Expansion Gear (author's).



Section on line A B.

in a full charge of air only during the suction stroke, a portion of this is expelled on the compression stroke, while at the same time gas or hydro-carbon vapour is added to the rest. The French inventors Forest and Gallice, patent No. 22,559 of the same year, varied this procedure. Taking advantage of the fact that in a four-cylinder motor, one piston is charging while another is compressing, they reduce the charge by transferring part of the contents of the compressing cylinder to the charging cylinder. Both these methods eliminate negative work in charging; but, like volume throttling, they adversely affect efficiency and power.

Fig. 15.



The dark shaded wheel is on the crank. The light shaded wheel is on the connecting-rod. The plain circles show position of the wheel on the connecting-rod at the end of the revolution.

Note.—Maximum stroke of piston A B equals twice throw of crank plus pitch diameter [2] of wheel. Minimum stroke of piston C D equals twice throw of crank minus pitch diameter [2] of wheel.

Another method of procuring increased expansion by diminished charge is illustrated in motors governing on the exhaust. To reduce the fresh charge, more or less of the exhaust is retained in the cylinder. It is intelligible that the practice should be economical; for, though back-pressure is created and the charge diluted, suction below atmospheric pressure is avoided, and, which is the main point, compression is preserved. The Gas Motoren Fabrik Deutz, in their patent No. 2729 of 1892, ingeniously eliminate all back-pressure by giving a free-exhaust stroke, drawing back part of the exhaust during a portion of the suction stroke, then closing the exhaust valve and opening the charge inlet valve for the remainder of the stroke. Taken broadly, as a principle, increased expansion by charge reduction might, perhaps, be useful in designing motors liable to temporary demands for power in excess of their normal yield, as, for instance, in hill-climbing. In such case, the cylinder would be so dimensioned that a full charge would provide very high compression and increased power for use on occasions when a temporary increase of vibration, &c., would be of no consequence. For normal running, the reduced charge and lower compression would be employed.* Against the advantage of this reserve power would be the slightly increased dimensions and weight of cylinders, &c. On the other hand, provision of reserve power is, with single-acting Otto engines, the only way to reduce change-speed gears to a minimum—a step much to be desired.

Other inventors have worked in quite a different direction, seeking greater expansion by increase of the working stroke. By lengthening the sweep of the piston during the working stroke, additional expansion is obtained. Such mechanical contrivances as the Atkinson linkage, though undoubtedly economical, are too cumbersome for car work. A simple device for the purpose was recently designed by the author, the detail being worked out by Mr. A. Suggate.

---

* This principle is adopted by the Franklin Manufacturing Co., Syracuse, New York. In normal work, the motor is throttled down much below its maximum capacity. The full power is used only for the severest hills, or the highest speeds.

The modifications of the stroke will be easily understood from the sketches given, Figs. 14 and 15 (pages 711 and 712). The diagram shows teeth on a fixed pin in the cross-head to gear into a similar wheel fixed to the crank. The pin on the connecting-rod is lengthened beyond the teeth to form a bearing, working in a block or roller, the latter sliding or rolling in a groove on the crank. This bearing takes up much of the thrust, leaving to the teeth the work of keeping the pin in the proper position in the crank. The shaft must, of course, be provided with suitable bearing. From the diagram it will be seen how the other strokes are varied during the cycle. Naturally it is not suggested that such gear would stand the shock of large engines, but for small powers the mechanism might serve its purpose. The cycle itself favours economy, for a light charge is used with high compression and increased expansion.

Other inventors again have aimed at increased expansion by additional cylinders. Excluding the system of compounding,* which is not likely to be introduced in light motor-cars, adaptations of the above principle have found, and others may find, a possible application to motor-car work. Engines of the Burt so-called compound, but more strictly expansive Otto type, are too heavy and complicated for this class of work. A clever method initiated, perhaps, by the Atkinson engine and adopted in such motors as the Koch, Gobron-Brillié, Hyler-White, Prétot, &c., is the use of two pistons in one cylinder (in this sense two cylinders). The plan gives rapid and good expansion, but is attended with some obvious disadvantages, which, however, have not prevented it from finding favour with many automobilists. Another ingenious way of increasing expansion is illustrated in the "Scott" vertical high-speed engine of Messrs. Reavell and Co. The bottom end of the cylinder is closed and is therefore equivalent to a second cylinder. There is no compounding, but increased expansion is got by the alternate use of the top and bottom ends of the same cylinder. At the termination of the down or power stroke, steam is transferred to the underside of the piston, working expansively on the upstroke,

* With separate high- and low-pressure cylinders.

during the latter half of which the residual steam in the top cylinder is compressed in the clearance space. Fresh steam is then admitted and the cycle repeated. The method gives increased expansion, very perfect cushioning, and freedom from drop on the release of the high pressure or top cylinder. Some such arrangement might be applicable to the Otto cycle.*

Cylinder Cooling.—This is the second point on which something has to be said. For any but the smallest motors, air-cooling, except as a supplementary aid, is impracticable, or in any case vastly inferior to water-cooling.

This latter system may be sub-divided into forced and natural. Of these, the former, by far the more general,† is affected by pump, usually of the centrifugal type; the latter, by placing the water tank higher than the cylinders, circulation follows the difference of temperature. The security of this system is its only strong point. In other respects it is inferior to forced circulation. Not only to maintain a given cylinder-temperature, does the slower circulation require a larger body of water to be carried; but the very cause of the circulation is defective. In the jacket, water rises upwards round the cylinder, because it becomes hotter. It is thus placed in a condition to exert the least cooling effect,‡ where it is most wanted, round the combustion chamber and valves. The result is an increase in the natural tendency to unequal cylinder expansion, which adversely affects the casting, the piston-rings, and general running of the engine.

---

* In patent No. 16,366 $\frac{9}{6}$, G. G. and R. O. Blakey. At a certain point in the stroke, a portion of the explosion gas is transferred to the front of the piston, working expansively on the return stroke.

† In this country and on the continent, also in America this year. Last season in the United States, one-half of the automobiles used forced, and one-half natural circulation; this year, twenty out of twenty-three employ forced, and only one the gravity system.

‡ It would be preferable, even with pump circulation, to introduce the cooling water at the top of the cylinder and withdraw it at the bottom.

Possibly the best method of all, and certainly the safest, would be a combination of the two systems. Where pump circulation alone is employed, it is advisable to provide against over-heating due to breakdowns. The safeguard, usually supplied, is a float glass on the dash-board, in which the position of the float indicates the maintenance of the circulation. But this requires the driver's attention, a demand to be avoided. A very ingenious French method, communicated to the author by Mr. Dugald Clerk, for indicating the piston water circulation in gas-engines, is to lead the discharge into a tank, fitted with a ball-cock, connected with the gas valve. If the circulation fails, the tank water-level falls, the ball-cock sinks, cutting off the gas and stopping the engine before damage is done. On somewhat similar lines, the author recently suggested fitting on the pump discharge pipe a lift valve, so connected with the electric ignition or the petrol supply that, as long as the cooling water circulated, the valve and its connection remained in their normal position; but, if the pump failed, the fall of the valve back to its seat broke the electric current or the petrol supply, and so brought the motor to a standstill. A mercurial tube in connection with the cylinder jackets offers another method of interrupting the firing, when, owing to a pump failure, the cylinder temperature becomes dangerously high. *

An ingenious method of avoiding air or water cooling is described in Patents, Nos. 24,091, and 24,311 $\frac{96}{}$, J. T. Dawes. Inside the cylinder is a layer of non-conducting material, then a thin metal liner. The trunk piston, closed at the end, works outside the cylinder, a forked connecting-rod being used. The inside of the cylinder is thus kept very hot, while the outside is sufficiently cool for running.

The question of what is the proper cylinder temperature is one that admits of two answers, according to the standpoint taken, namely, that of efficiency or that of power. A very considerable heat loss arises from the cooling of the explosion gases by contact with

* Other devices—Patent No. 779 $\frac{93}{}$, A. Shiels (Electric Alarm); No. 884 $\frac{95}{}$. E. Capitaine (Fusible Plug).

the cylinder-walls and piston. Hence the higher the temperature of these latter, the lower their cooling effect. High cylinder-temperature, therefore, conduces to efficiency, considered as the ratio of heat converted into work to the total heat imparted to the engine. Under this aspect then the cylinder walls should be kept as hot as they can be efficiently run. But, when power is considered, different considerations intervene. Other conditions being alike, the more charge that can be included in a cylinder of given dimensions, the more power will be produced by the explosion. Thus power depends on the weight of the charge. Now one charge, having half the absolute temperature of another, will have double its weight, and its explosion will generate proportionately greater power. Low temperature, therefore, by diminishing the heat of the incoming charge, favours increased body and therefore increased power. In connection with this subject, Professor Hele-Shaw presented to the International Engineering Congress at Glasgow in 1901 a summary of power tests * confirmatory of the above. His series of experiments showed that in a motor with jacket water ranging from 77° F. to 250° F. there was, with increase of the water temperature, a gradual decrease of horse-power declining from 4·775 B.H.P. to 3·94 B.H.P. A determination of the engine speed and quantity of water circulated was omitted, but the figures are still interesting as an illustration of the effect of cylinder temperature on power. In 1896,† Mr. James Atkinson stated that for every 5½° F. by which the charge in the cylinder was reduced in temperature before compression, one per cent. more power could be obtained from the engine. Low cylinder-temperature results in easier lubrication, and, therefore, likely enough, in reduced friction, a possible factor in the increase of power.

As coolers, various types of radiators are used, with or without auxiliary fans, these being useful adjuncts in hot climates or for long hill-climbs. In patent No. 8471 $\frac{97}{}$, P. Royer uses the mudguards as tubular radiators. Cylinder cooling by water injection has already been noticed.

---

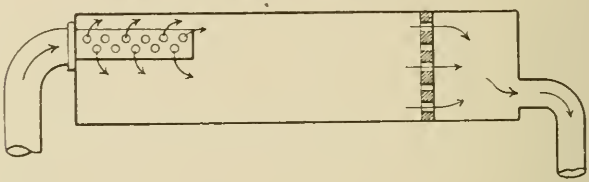
* Proceedings 1901, page 791.

† Proceedings Institution Civil Engineers, 1895–96, vol. cxxiv, page 163.

Mufflers or Silencers.—Until very recently these have been considered merely as sound-deadeners,* and their influence on engine power quite overlooked. Many of the silencers used were thus ridiculously small, giving rise to quite unnecessary back-pressure. What is the proper volume ratio between the silencer and the cylinder the author does not know. Mr. W. A. Norris states that it should be a minimum of 5 to 1.† The point could be easily settled by any manufacturer that would take the trouble to make the simple experiment. That silencers are probably yet too small, and that considerable throttling still exists, is evident from the fact that

FIG. 17.

The 40-H.P. Simplex Silencer (Mercedes).



The end of the exhaust pipe is plugged and perforated.

certain American makers (*e.g.*, the Friedman car, the Murray car) have added to the exhaust pipe between the cylinder and silencer a by-pass valve, to free the exhaust, when more power is required. This method has been followed in the English Brooke car, Fig. 16, Plate 78, and the German Daimler, Mercedes Simplex. It is a useful addition, not implying that the silencers of these makers are less efficient than those of others. The illustration, Fig. 17, shows a common form of muffler. In the American Friedman car the silencer consists of concentric tubes, communicating with one another through perforations. The exhaust from each cylinder

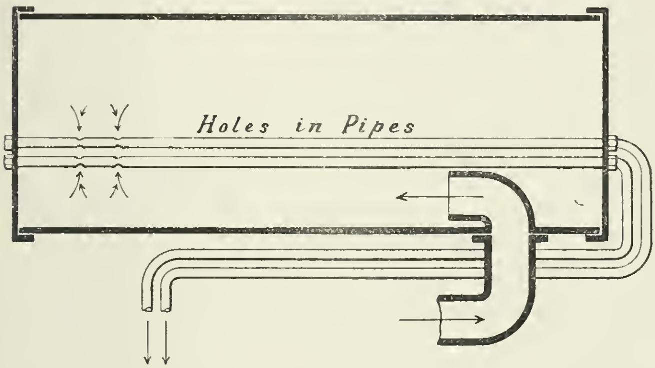
* Patent No. 8197$\frac{95}{}$, E. Turner, describes a silencer fitted with spring piston for effecting water circulation—an ingenious use for the exhaust.

† For volume of silencer, best calculated to save power, H. E. Homans ('Self-Propelled Vehicles," page 384) cites Roberts' formula: $v = 3 \cdot 5$ (cylinder diameter)^2 × (length of piston-stroke in inches).

enters at opposite ends of the central tube, and diffuses outwards. The silencing effect is said to be very complete. Another American silencer, the Oldsmobile, will be understood from the illustration, Fig. 18. The exhaust gases are given ample space to expand, and as their passage through the perforated tubes to the atmosphere is slow and continuous, it is said to be noiseless.

To ensure immunity from fracture in case of back-fire, a relief valve is sometimes fitted to the muffler.

FIG. 18.
Silencer (Oldsmobile).



Communication of the Motor-Power to the Car.—(a) Crank and Crank-shaft.—As regards the position of Otto-cycle motor crank-shafts, the practice is to set the centre of shaft below the axis of the cylinder. The method is open to objections. All Otto-cycle motors are single-acting, high-speed engines of accentuated type, in as far as the initial pressure is greater, more violently applied, and more rapidly repeated—constantly in one direction, namely, on the downward stroke. This sudden blow, always applied in the same direction, throws a heavy strain on the connecting-rod and crank-shaft, and, in large power gas-engines, necessitates crank-shafts of about half the diameter of the cylinder. This is one of the mechanically weak points of all engines using the Otto cycle. The question is whether the present practice deals in the best way with this defect.

The prevailing method of locating the shaft line, so as to intersect the cylinder axis, gives equal angularity to the connecting-rod on its up and down stroke. The cycle, however, imposes all the working strain during the down stroke; consequently, construction should, perhaps, aim at keeping the connecting-rod in the most favourable position to withstand pressure in this period of the cycle. In other words, the angularity should be reduced during the working stroke, being proportionately increased for the idle strokes; less angularity when the pressure is great, more angularity when it is slight. An additional advantage is that the crosshead is kept constantly pressed against one guide, if the shaft is half stroke away from the axis of the cylinders, consequently there is no knock from bar to bar on turning centre. All that is needed to accomplish this is to set the crank-shaft in advance of the axis of the cylinder. This, as regards motors, excepting in the Duryea car, would be a new departure; but it is not unknown in the modern, single-acting, high-speed steam-engine; and the reasons for its use in the latter are certainly more cogent in the case of the former. In steam practice the Peache high-speed engine, made by Davey, Paxman and Co.,* and the Westinghouse single-acting engine might be cited as instances of this method of construction—a method which motor manufacturers might do well to copy.

On the question of material for crank-shafts, one of the prominent firms in this country informed the author that the steel from which they forged motor-cranks averaged 32·5 tons per square inch tensile strength, that is to say, not below 30 tons nor above 35 tons, and

* Extract from letter of Messrs. Davey, Paxman and Co., 28 June, 1902. "The shaft in our Peache engine is put out of line for the reason you describe, as the engine is single-acting, and we do not expect to abandon the practice, even for large engines. At present, the biggest Peache engine is 800 I.H.P., and 260 revolutions per minute. No doubt the position is theoretically correct, and practically the plan works well." In "The Autocar" (19 July), the Duryea Co. wrote: "This method of construction has been in use upon Duryea power carriages for the last three years, and has borne out expectations to an extent which will perhaps be better understood when we say that, although the crank-shafts of a 10-H.P. engine weigh barely 14 lbs., we have yet to hear of a broken one, and there are some hundreds in use."

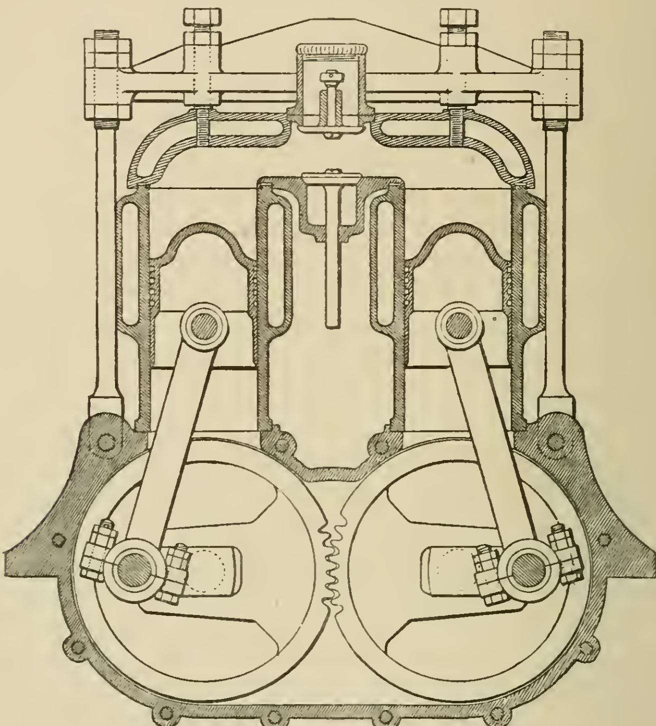
containing 0·05 per cent. of phosphorus. They considered this steel less liable to fracture as a result of constant vibrations, shocks and jars. The author does not at all agree with this view. He believes that for small crank-shafts (also connecting-rods, etc.) a more rigid steel, of very much higher tensile strength, at least 45–50 tons, with even lower phosphorus, is a far more suitable material. A milder steel retreats before impact, yields and deflects, and it is this repeated deformation that does the damage. This is especially the case where, as in high speed single-acting explosion engines, the stresses of torsion and bending are so quickly and frequently repeated and reversed. The elastic limit and ultimate tenacity of these higher tensile steels is very much higher than those of milder quality, and as they are rigid and unyielding, there is no deflection to add to the strain of the metal, and to wear down the inner sides of the bearings, and thus aggravate the bending tendency. For these small forgings, steel of higher tensile strength is easily obtainable with equal safety, and should be specified by motor makers. For such purposes nickel steel has many claims to consideration.*

(*b*) *Fly-Wheel.*—There is little to be said on this detail. The inertia of the fly-wheel is one of the chief causes of vibration, the explosion energy imparted to the wheel reacting on the frame. A very radical elimination of this objectionable feature is the provision of two fly-wheels revolving in opposite directions. This method has been successfully worked out in the English Lanchester car, and also

* In reply to the author's enquiry on this point, Col. Holden, R.A., wrote: "I personally should prefer steel with a much higher tensile strength;" while Captain Sankey, R.E., replied: "For small engines, in which lightness is of paramount importance, and there is no difficulty in getting the amount of bearing surface, high tensile steel is, I think, the best, so long as it also has sufficient elongation and contraction of area. Nickel steel seems to be the kind of steel to use in such a case." For machinery parts, subject to alternating stresses and wearing action, Mr. H. F. J. Porter, of the Bethlehem Steel Co., is said to recommend steel of 85,000 lbs. tensile strength, 40,000 elastic limit, 15 per cent. elongation in 4 diameters; or after tempering, 90,000 tensile strength, 45,000 to 55,000 lbs. elastic limit, and 15 to 20 per cent. elongation. By introducing 3 per cent. nickel, the quality is raised (see Appendix II, page 747).

in the French Crozet (Tourand) motor, Fig. 19. A large, more especially large rimmed, and, therefore, preferably a built-up fly-wheel, is by no means to be despised, since it conduces to steady running;

Fig. 19.
Motor (Tourand).



facilitates easy change from low to high gear; helps starting on hills and heavy ground; extends the speed range, enabling the motor to run slower without pulling up; reduces fluctuations of rotative speed, and thus the stresses on all driven parts, gear, chains, and tyres. Naturally multiple-cylinder or high-speed, or low-compression motors, require less fly-wheel than single-cylinder, slow-running or high-compression engines.

(*c*) *Clutch.*—The function of the friction clutch is to transmit motion from the fly-wheel to the gear. A good deal of trouble used to be experienced with clutches getting out of alignment, slipping, acting too fiercely, etc. Nowadays these difficulties have mostly disappeared. One of the best methods of ensuring accurate alignment is to mount the internal part of the clutch on the engine-shaft, prolonged through the fly-wheel, as in the 8-H.P. Hozier car. In the 16-H.P. Panhard chassis, recently shown at the Crystal Palace Exhibition, the clutch, Fig. 20, Plate 78, was mounted on a sort of Cardan joint, allowing a certain vertical and lateral motion—also a good way to obtain regular engagement all round. In other cases, provision against defective alignment is made by setting springs under the friction strip (leather, copper, etc.) with which the clutch is faced.

In all cases clutches are pressed against the recessed fly-wheel by springs, usually helical. In the best practice, the thrust of the spring is regulated by an adjustable nut, etc., and is prevented from reaching the engine bearings by the interposition of a ball thrust bearing, as in the Daimler, Mors, and other cars.

In most cars the application of the foot-brake withdraws the clutch; and, in the Mercedes Simplex of the Canstatt Daimler Co., the withdrawal of the clutch automatically reduces the speed of the motor—a very neat arrangement.

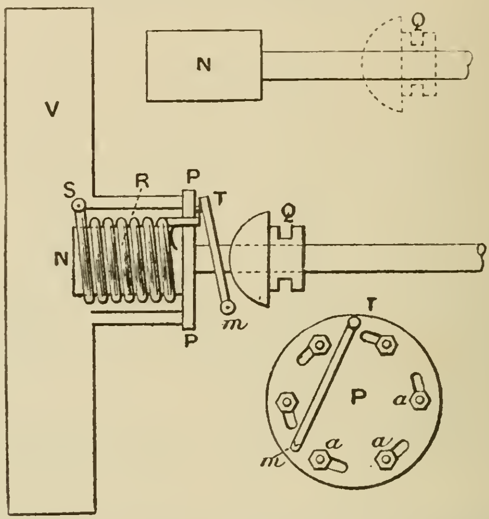
One of the latest forms of clutch is that employed on the German 40-H.P. Mercedes, Simplex, Daimler car, Fig. 21 (page 724). Here the ordinary clutch is replaced by a spiral spring fastened at one end to the fly-wheel, which in this case serves as fan. When in action the spring is caused to coil tightly round a small drum on the driving axle. The idea is in many respects excellent. Messrs. Panhard and De Diedrich have introduced new clutches, and the Canstatt Daimler Co. is said to be experimenting with an electro-magnetic arrangement. Colonel Holden has for some time been experimenting on the same lines.

Transmission from Clutch to Gear.—The main point noticed is the increased use of universal joints at both ends of the transmission shaft, so as to prevent deflection strains reaching the gear. In the French 8-H.P. Clement car, behind the spring adjusting nut, the

clutch shaft ends in a squared section, the faces being given a slight longitudinal curvature to allow for deformation of the frame. The clutch-shaft and change-gear shaft are united by a sleeve, inside of which is a distance piece. By opening the coupling sleeve and removing the distance piece, the clutch and shaft can be removed; this is a very handy device. The English Daimler, and, presumably, most other companies, have very similar methods.

Fig. 21.

Details of New Clutch (Mercedes).



R spiral spring fastened to the flywheel at S, and connected on the disc P to an operating lever T, actuated by special sliding cam Q. N drum gripped by the spring in action.

There is an indication, however, that these universal joints will be dispensed with, and greater rigidity obtained by tying all parts to a single frame. There is no objection to a single frame properly tied, but flexibility of drive, the author thinks, should be fully maintained, if not increased. To this end he suggests the trial of flexible transmission shafts, constructed on methods, illustrated by the coiled spring, the bundle of steel rods, etc. Such shafts provide not only for want of alignment, but also, by reason of their initial

twisting, absorb the heavy jars and strains when the clutch is too fierce or too suddenly applied. The same method of construction might perhaps be applied to the countershaft between the differential and the sprocket pinions.

Change-Speed Gear.—The various systems in use do not present much novelty. Four methods predominate: toothed wheels which are slid in and out of gear, the Panhard type, very generally used; gear-wheels* always in mesh, but fixed, when required to drive, by interior expanding clutches, used, for example, by the Société des Automobiles Crouan, Paris, less common, but likely to become a great deal more so; belt-gear, as in the Benz cars, fast disappearing; epicyclic gear, running solid for the high speed, found chiefly in light cars; lastly a link motion, by which varying throw is imparted to rods which drive the differential, on the rear axle, through reciprocating clutches. Only one instance of the use of this method is known to the author, namely in the 2½-ton lorries, built by R. Hagen, of Cologne.

With gears the general tendency is a direct drive for the highest speed; that is, without the use of intermediate pinions between the motor and the differential. The Mors car may serve as illustration of the method, Fig. 22, Plate 79. At the end of the primary and secondary shafts there is the usual bevel pinion gearing into and driving the differential; this is in use for the first three speeds. The fourth speed is transmitted direct from the primary or driving shaft (that next to the motor) to the differential through a spur wheel, out of gear, for the first three speeds. Actuation is by a lever that, forcing back the driving shaft, leaves the intermediate shaft out of gear and engages the loose spur-wheel with the differential.

An ingenious idea has been realised by Mr. L. Megy of Paris. Dispensing with the hand change-speed lever, he causes the speed to automatically vary according to the resistance to be overcome. The gear-wheels are always in mesh, and on each of the loose wheels is a large collar or drum, inside of which is a leather disc. These discs

* Double helical, or fishbone, gearing is the least noisy.

are operated by a rod inside the shaft and are displaced by the resistance met with by the car. Thus, when the car begins to slow down on one gear, the rod moves forward and presses the leather disc on a lower speed wheel, and *vice versâ*. Any one speed, however, can be fixed by a hand lever. The car thus regulates its speed to the road, or can be regulated when required.

It is quite possible that change-speed gears may be soon driven out of the market, either by motors of sufficient flexibility or by some electric transmission of power from the motor to the driving-wheels. Or, though far less likely, by hydraulic gear. It is rather a sign of the times that Messrs. Panhard and Levassor should, it is stated, have taken over the Canstatt-Daimler and Lohne-Porsche French patents for a system in which the motor drives a dynamo, and this an electric motor on the wheels. A number of cars of this nature are, it is said, proving satisfactory.

Differential Gear.—In a few cases the differential has been replaced by other arrangements. Messrs. Brouhot et Cie. of France are said to employ ratchet clutches inside the hubs of the driving wheels. In taking corners, the outside wheel runs free, and on dropping down again to the same speed as the inside wheel, the ratchet pawl falls into the teeth for forward driving.

In the Swift voiturette also the road wheels are fitted with free-wheel clutches of the ratchet type, such, only on a larger scale, as are in use on bicycles.

Neither arrangement would appear suitable for reversing.*

In designing a differential, the pins should be of the strongest material and ample proportions, and every precaution should be taken to keep the gear free from any defect in the countershaft alignment. Universal joints in the latter can be used, and the flexible shaft as suggested might be tried.

* Patent No. 21,675 $\frac{96}{}$, C. M. Johnson, describes another substitute for the differential. The axle of the driving wheels is fitted with two friction clutches, one for each wheel. These clutches are connected by chains or equivalents to the fore wheels or axle, in such way that as one chain is tightened, on a curve, the respective clutch is released, and the wheel is free to revolve apart from the motor.

The weakness of the divided shaft is remedied in "the liner tube countershaft," or may be got over by placing the differential on the road wheel axle.

The defects of bevel differential gear are :—natural tendency of bevel gear to force itself apart, end thrust of the pinions against the collars, excessive wear and tear, cross strain on the bearings, loss of power by conversion at right angles. The same compensation is obtained by spur differential without the thrust and wear.

Systems of Driving.—The two systems of driving are the live axle and the double sprocket chain. The former seems the better mechanical job, but so far it is chiefly confined to light cars. A notable exception is the 40-H.P. Napier, on which Mr. Edge has recently won the Gordon-Bennett Cup. No development of the central chain drive has taken place.

It is difficult to understand why sprocket chains are left quite uncovered and usually without lubrication. Both could be easily effected.

Steering.—All first-class cars are fitted with irreversible steering gear, mostly of the worm and worm-wheel section, or preferably the square thread shank and sleeve or nut on account of the reduced wear, which in the former arrangement may soon produce backlash, Fig. 23 (page 729).

In the future, efforts should be made to embody resilient or absorbent members in the locked or irreversible controls, which at present transmit in their full force all shocks and blows from the front wheels.

At the time of the Paris Exhibition, a tendency was displayed towards utilizing the steering pillar or column for other purposes as well. Thus in the light car of Messrs. Seug et Henry, Romilly-sur-Seine, the column had three movements. In the vertical position, it put the brakes on and gave the driver room to mount or dismount. Pulled down to the second notch, the brakes were off, but the motor was still out of gear. In the third notch, the usual position for steering, the motor was in gear. In the Megy French car, when the pillar was

upright, the motor was out of gear; inclining the column to its steering position and pushing it down put the motor in gear; an upward movement threw the motor out of gear and applied the brake; while a further upward motion reversed the gear. The column could be fixed in any one position. The American Duryea car is another instance of a manifold use of the steering pillar. The practice is not, so far, extending.

Brakes.—Invention is still busy with this important detail of car construction, and there is yet room for an improved brake, perhaps hydraulic, pneumatic or magnetic. Several makers are abandoning band brakes on the driving wheels; and, in the author's opinion, the step is a wise one. The substitute mostly takes the form of an inside expanding brake acting on the inside of a special sprocket ring.* Messrs. Charron, Girandot et Voigt have introduced an expanding collar inside a drum on the wheel. The Canstatt Daimler use a powerfully built expansible ring clutch, acting within an annular flange, secured to the road wheel, as part of the sprocket. Messrs. James and Browne employ a double-acting brake, having two cast-iron slippers acting on the inside faces of the sprockets, Fig. 24 (page 730). Another form of brake is the French Rassinier, which substitutes the grip of rollers (rolling friction) for blocks (sliding friction) on an annular ring affixed to the rear wheels, Fig. 25 (page 731). It is said to be impossible to fire the brake or affect its grip by grease.

The water-cooled band-brake on the differential, and occasionally on the countershaft as well, shows no alteration. Neither of these positions is commendable.†

---

* Expanding ring brakes are more easily protected from dirt, damp, and oil, which greatly affect the frictional properties and the wear of hand brakes.

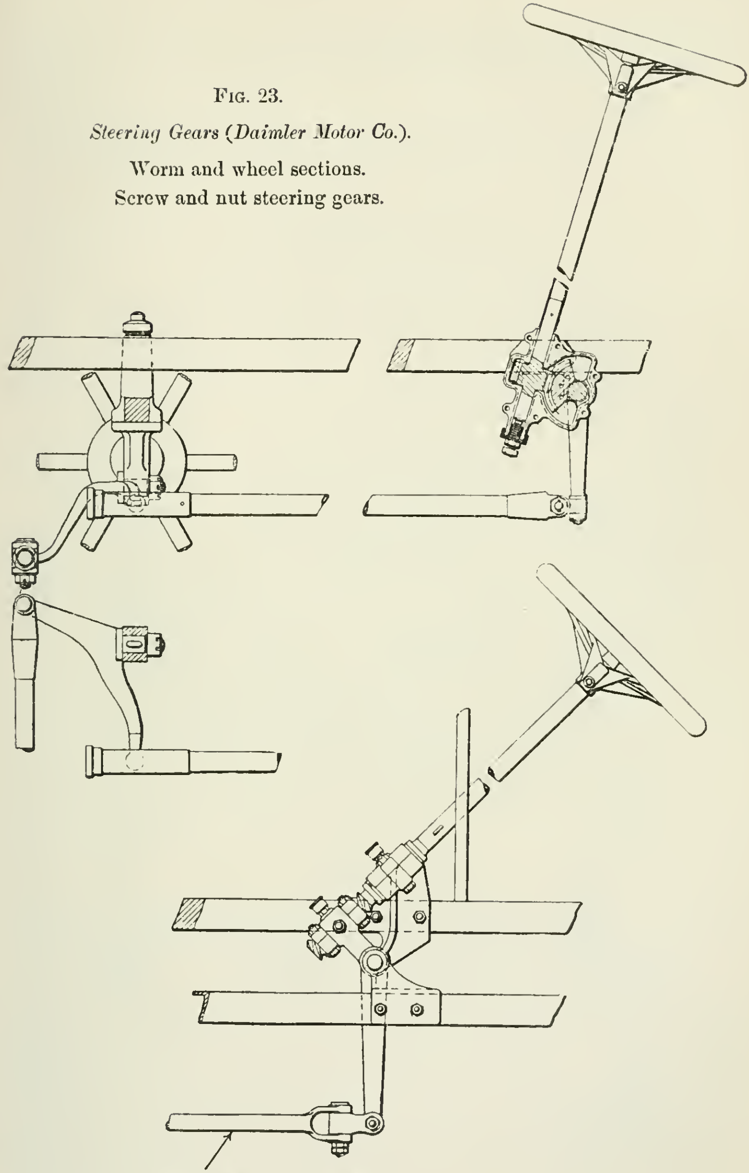
† Brake power becomes effective at the tyre surface, hence the greater the number of intervening parts, the greater the chance of brake failure. By direct application to gear, the latter is more severely taxed. Brake action on the differential is likely to cause skidding, if one wheel is on slippery ground; in any case the stopping power would be greatly reduced.

Fig. 23.

Steering Gears (Daimler Motor Co.).

Worm and wheel sections.

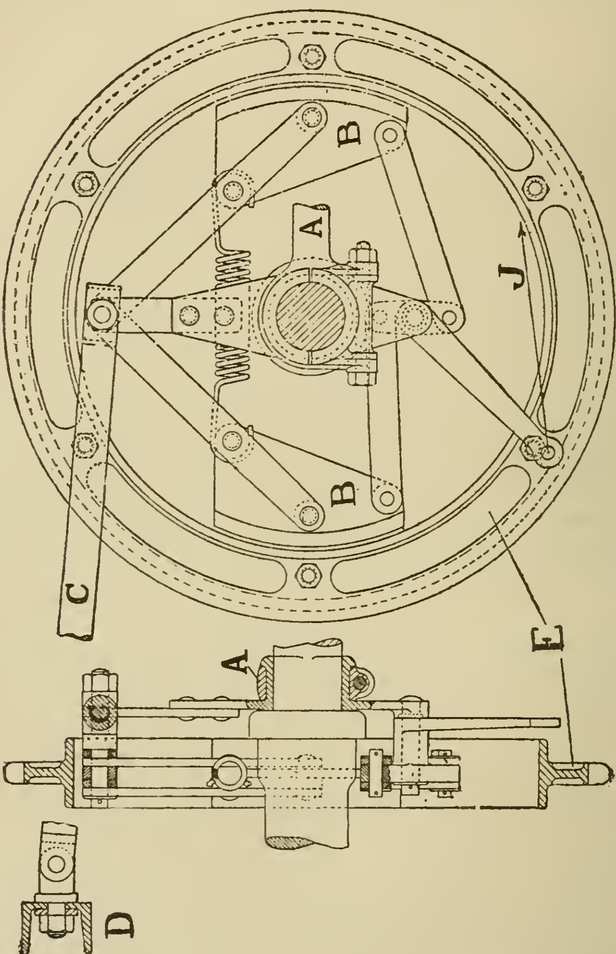
Screw and nut steering gears.



Connected to steering arms on front wheels.

In almost every case, operating the footbrake withdraws the clutch and in some cases throttles the motor.

Fig. 24.
Rear Wheel Brakes (James and Browne's).

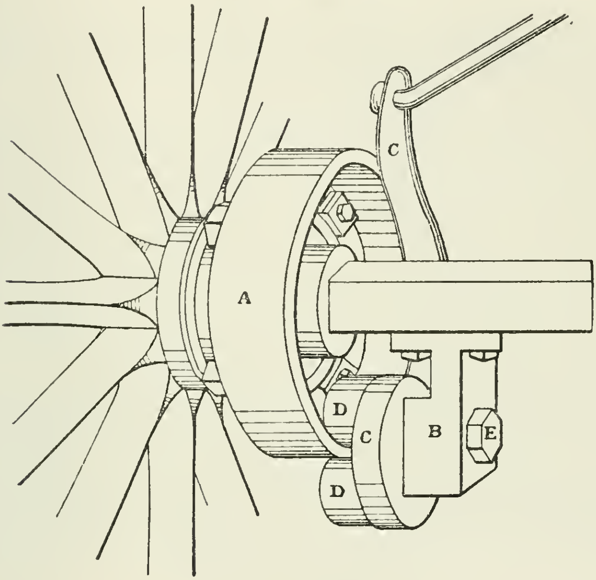


A, distance rod; E sprocket wheel and brake drum; C stationary member attached to frame at D; J lever operating the brake blocks at B B.

Axles.—It is a strange thing that no English firm appears capable of turning out motor-car axles of quality and accuracy equal to the production of French and Belgium firms. The Wolseley Co., as might be expected, make their axles from Vickers' special axle steel, but other leading firms import largely from foreign makers.

Fig. 25.

Brake (Rassinier).



A, annular ring attached to hub or spokes; C C lever fulcrumed on shaft E and pressing rollers D D against the brake ring surface.

An enquiry to one of our large forging firms for an explanation of this fact elicited the reply that there appeared to be nothing in the material itself to differentiate it from the steel of this country, and that if any superiority existed, it must be due to a method of hammering which was more or less a lost art in England. The author, after visiting the French factory and seeing their methods of

manufacture, advised a firm of English manufacturers to import a few leading hands and start home manufacture; but the advice was not followed, and so far the trade is allowed to remain in the hands of the foreigner.

The employment of weldless steel-tube or hollow bored axles, which is the latest development,* ought to suit British makers, and if this type of axle proves successful, British-made axles ought to be found on every car.

Springs.—The same remark as to the superiority of the foreign-made article applies to motor-car springs.

The firm of Lemoine et Cie. have a special reputation for such goods. For the purpose of more closely studying their process, the author visited their works, and also the Paris establishment of Messrs. Rothschild. Although naturally reticent, Messrs. Lemoine stated that the spring steel they used was a special brand made exclusively for their use by Messrs. Holtze of Unieux, Dept. Loire, the metal containing manganese and a certain percentage of silicon. Every spring was tested before delivery, and the tests witnessed by the author showed excellency both as to quality and make.

By far the majority of the springs used by French makers are of the Grasshopper type, fairly broad, flat and long. Length is a point on which both Messrs. Lemoine and Messrs. Rothschild lay stress.

The choice of spring dimensions naturally depends on several factors:—

The horse-power of the car.
The weight of the car.
The length of the car.
The speed of the car.
The elasticity desired.

---

* Hollow axles appear to have been taken from the French. In what seems the best method of manufacture, the axle is forged with certain outside enlargements, desired as re-inforcements in the interior. The forging is then bored from end to end. It is next heated and pressed in dies, which remove the enlargements from the outside and cause corresponding contractions of the bore at these places. The axle is then given the desired curve, hardened, tempered, and finished in the lathe.

Generally speaking, springs should not be less than one mètre in length, preferably more. For light cars they should show when loaded a deflection of 15 to 30 mm. for every 100 kg. of dead weight. In heavy cars the deflection may be as low as 12 to 13 mm. per 100 kg. of dead load.

The customary method of application is to support the frame on springs; but in the Rothwell Light Car, built by the Eclipse Machine Co. of Oldham, the body is carried by springs on the frame, and the vibration is said to be reduced. In a few cars a cross spring is added to the side springs, and this no doubt tends to break the periodicity or rhythm, which, occurring in any one system of springs, may accumulate to a disagreeable swaying.

Though not in use, numerous patents describe spiral springs for automobiles, and there seems no particular reason why they should not be employed, especially for heavy drays, &c.

With the object of saving the springs and preventing the wheels from jumping from the road at high speeds, pneumatic buffers form a new feature in the 80-H.P. Mors car raced by Fournier in the late Gordon-Bennett Cup competition. A pneumatic cylinder is fixed to the frame, above each front spring, while the piston-rod is attached to the axle, Fig. 26, Plate 79. Above each rear spring, two pneumatic cylinders or dash-pots are similarly fixed.

Endeavours have been made to save the motor also from jar, by rubber suspension buffers, as illustrated, Fig. 27 (page 734). With a flexible drive and flexible pipe connections, the plan might be serviceable.

Frames.—Most makers are now using a longer wheel-base and a broader frame, giving greater space for large roomy bodies.

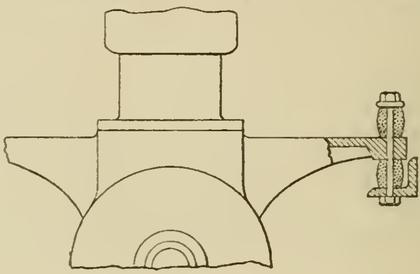
Whereas until very recently the engine and mechanism were usually carried on an under-frame, and deflection provided for by universal joints on the shafts, &c., the most recent practice, illustrated in the 40-H.P. Mercedes Simplex car, dispenses with the under-frame and universal joints, and carries engine, bearings, gear, &c., on the main frame, which is braced and stiffened for the purpose, Fig. 28 (page 735).

As regards material, car frames are mostly of armoured wood, then stiffened or backed by girder-shaped steel plates. For the recent Paris-Vienna race, Messrs. Charron, Girardot et Voigt forced the square section wood into thin weldless steel tubing, which takes the same shape, and fitting tightly to the wood is stated to give, as it is likely to do, greater rigidity than the other method. In a few cases, as in the new De Dion light car and in the Humber 10-H.P. car, a tubular frame is used; in this latter case probably due to the great familiarity of the Company with this class of work. In 1903, pressed-steel frames promise to be popular.

Lubrication.—In this respect, there is nothing very new or noteworthy. The innumerable toy grease-cups that used to adorn

FIG. 27.

Method of attaching Motor to an Angle Frame, by Rubber Buffers.



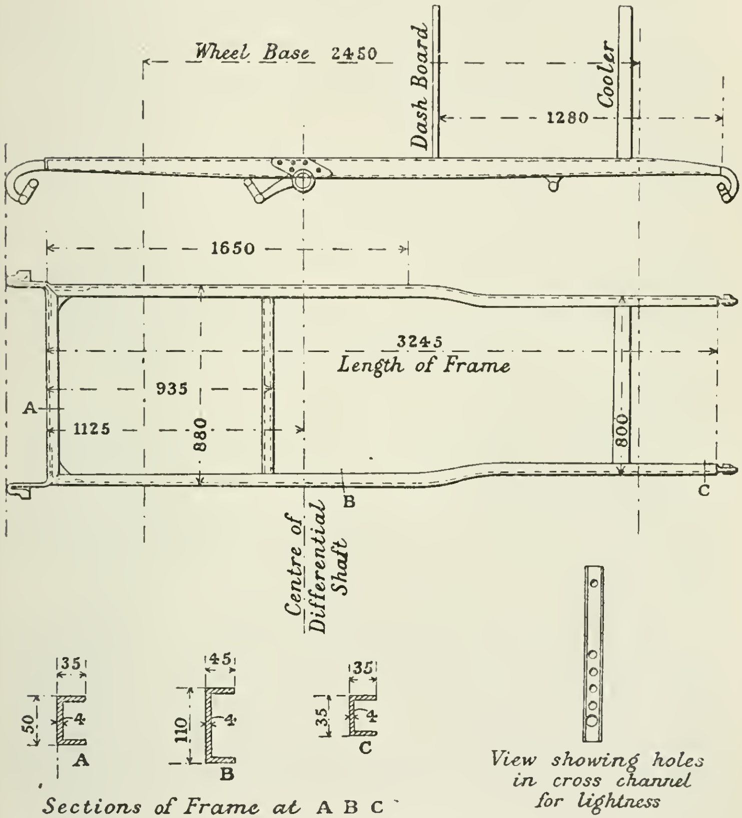
the mechanism of cars have been replaced mostly by sight drop-feed oil lubrication. In a few cases, the preferable forced or circulating pump lubrication is employed. In the Wilson and Pilcher car, this excellent system is used throughout, the oil being drained back, filtered and re-used. In the 35-H.P. Mercedes car, lubrication of the engine, engine bearings, and change-speed gear is provided by an oil pump, chain driven off the half-time shaft. In the 20-H.P. Maudslay car, the engine shaft is extended forward, and by means of worm gear, drives two barrel pumps fixed on the frame. In both cases the oil returns to a reservoir and is filtered for re-use. All pumps, whether for oil or water circulation, should be gear driven.

Change-speed gears are generally run in oil; and crank-shaft lubrication is of the splash, collecting cup or ring type.

A very usual method of crank lubrication in modern high-speed steam-engines, is to fill the crank-chamber with water to a depth

Fig. 28.

The new 40-H.P. Simplex Frame (Mercedes).



covering half the crank-pin on the down stroke, floating oil on the top. This plan has two advantages. The churned oil and water furnish better and more ample lubrication than oil alone, while the

gradual evaporation of the water prevents the temperature rising over 212° F. It would be worth trying the same plan for motor cranks, provided, which with the piston fit and temperature does not seem likely, that water did not find its way into the combustion chamber, and that evaporation was not too rapid ; the addition of water would not only improve lubrication, but very considerably cool the piston and cylinder walls, whilst at the same time it would provide a volume of lubricant enabling the engine to run safely, should the oil-supply temporarily fail. It is unnecessary to add that the crank-chamber must communicate with the atmosphere by pipe or otherwise.*

So far as the author knows, the Duryea car is the only make that sensibly provides oil-pad lubrication for the pins of the driving chains.

There is rather an interesting question as to the temperature which bearings may be allowed to attain for maximum efficiency. The following figures recorded in the "Uhland's Technical Rundschau" represents the result of certain German experiments. The running conditions remaining the same, the friction decreased with the increase of the bearing temperature, up to a certain point in the following proportions :—

Temperature in degrees Cent. . . .	29°	49°	64°	82°	93°	115°
Friction in lbs. English	8·0	7·5	6·0	5·0	6·5	7·0

At 82° C. the friction is a minimum, it then begins to increase ; at 115° C. it is still 1 lb. less than at 29° C. Warm, though not hot, bearings, therefore, appear to be advantageous.

There is also another interesting point that so far appears to have escaped the attention of the chemist and the engineer—the effect of lubrication on charge-firing. At certain temperatures and pressures, trouble is experienced by premature so-called automatic firing of the petrol mixture. It has been stated, and by authorities of standing,

---

* Since writing the above, the author has found the method applied to oil-engines, patent No. 11,930 $\frac{97}{}$, P. A. Esteve, but in this case for purifying purposes.

that petrol charges cannot be compressed to much over five atmospheres without risk of premature firing. What this represents in temperature is difficult to say with accuracy, since one factor—the working temperature of the cylinder wall—has not been determined. Owing however to the thinness of the metal and the steepness of the heat gradient, it is probable that no great difference exists between the mean temperature of the inner and the outer skin, and that the mean temperature of the whole consequently is not greatly in excess of that of the jacket water. Although no temperature measurements seem to have been taken, certain considerations would appear to fix this temperature at from 200° to 250° F. Assuming therefore the incoming charge to attain this temperature, and then by further compression to 75 lbs. to receive an additional rise of 374° F., its final temperature will be from 574° to 624° F., which would stand as the critical point of automatic ignition. The principle and fact of ignition by compression is so well established in the minds of engineers that, for example, Messrs. De Dion and Bouton have patented a self-igniter,* consisting of a small cylinder in communication with the main cylinder. A piston compresses a little of the petrol mixture, and the ignition striking back fires the charge. Now, the point raised by the author is this: Is the automatic ignition of a petrol mixture possible under any temperature attainable in a water-cooled motor? He doubts the possibility. With a view to testing it, he recently took a $3\frac{3}{4}$-inch $\times$ $4\frac{1}{2}$-inch tin case, with tightly fitting cover, and successively introduced two, four, and six drops of petrol, then placing the case over a Bunsen burner. At each attempt the heat was increased until the solder melted. In no case did ignition take place. He then took a jointless stamped tin case, $3\frac{1}{2}$ inches $\times$ 1 inch, and tried unsuccessfully with four and six drops of petrol to obtain explosion at partial red heat. Repeating the tests, using instead of petrol a cylinder lubricating oil of 410°–430° F. flash point, 440°–460° F. fire test, 910–915 density, ignition was readily obtained.

* Described and illustrated, "Horseless Age," 20 Aug. 1902, page 200.

Not satisfied with the sufficiency of these results, the author questioned Messrs. Carless, Capel and Leonard as to the temperature at which petrol vapour and air would ignite. On 29 August they replied: "From our experience we should have thought it would be impossible for a mixture of petrol vapour and air to ignite, except on the application of a light." He then addressed an inquiry to Mr. A. Phillips of Reading, as to the temperature of premature ignition in air-cooled motors. The answer was: "From practical experience with air-cooled motors I find that explosion usually takes place when the walls of the explosion chamber are just below red heat."

There are, therefore, the following phenomena:—

1st. Failure of petrol vapour and air to ignite at even partial red heat.

2nd. Ignition of lubricating oil under similar conditions.*

3rd. Automatic ignition of petrol charges in water-cooled motors at comparatively low temperatures.

4th. Similar ignition in air-cooled motors at higher temperatures. The conclusion to which these phenomena point is, that the automatic ignition of petrol charges is due, not to compression or temperatures attainable under running conditions, but solely and directly to the ignition of the lubricant employed. It takes place at a fairly low temperature in water-cooled motors, because the oil used has a comparatively low flash-point; and it occurs in air-cooled motors at

---

* "It is a curious and interesting fact that, with heavy oils, ignition is more easily accomplished at a low temperature than with light oils. The explanation seems to be that, in the case of light oils, the hydro-carbon vapours formed are tolerably stable from a chemical point of view, but the heavy oils very easily decompose by heat and separate out their carbon, liberating the combined hydrogen, and, at the moment of liberation, the hydrogen, being in what chemists know as the *nascent* state, very readily enters into combination with the oxygen beside it. In this manner combustion is more easily started with a heavy oil than with a light one . . . . It is a peculiar fact that oil vapour, mixed with air, will explode by contact with a metal surface at a comparatively low temperature."—"The Gas and Oil Engine," D. Clerk, page 423.

a higher temperature because the lubricant employed has a higher flash-point.

Turning for a moment to the lubricating oils in common use with water-cooled motors, the following figures are typical:—

Flashing Point.	Burning Point.
410° to 450° F.	460° to 550° F.

If the author's suggestion be correct, it might be supposed that three results would be noticeable:—

1st. Premature ignition would be more frequent when excessive lubrication was employed.

2nd. It would be continually occurring with lubricants of which the flash point was below 600° F.

3rd. It should leave evidence of its occurrence in the form of carbon deposit.

The first result is distinctly noticeable. The second and third results do not necessarily follow. As Mr. H. B. Case, managing director of the Vacuum Oil Co., recently observed to the author: "The assumption that decomposition begins at burning point may be accurate, but practice seems to show that decomposition does not go far enough up to a considerably higher point than the burning point to cause deposit of consequence. This seems reasonable in view of the fact that the flash and burning points are determined by an accumulation, during a considerable period of heating, of enough vapour to flash or ignite; and, in practice, the vapour escapes, as it is driven out of the oil. After one flash, an oil will go to a higher temperature before another flash occurs; and, if at the burning point the flame is blown out after ignition, the oil will go to a higher temperature before it will ignite again. The period of time, which will elapse before another flash or a re-ignition occurs, varies with the character of the crude petroleum from which the oil was made, and the processes of refining. The wide variation in these two things makes it impossible to deduce accurately from what one oil does, under given conditions of service, what another oil, even though similar in tests, will do under the same conditions." From this it will be seen that, to produce the results in question, three

conditions must be fulfilled:—There must be sufficient time for decomposition; sufficient oil to generate enough vapour to flash; and sufficient continuous burning to cause any deposit of consequence. In practice these conditions are not so frequently present. Excluding the suction stroke, when the temperature is too low for the purpose, the duration of oil exposure to vaporization or decomposition in the presence of air is confined to the compression stroke. The time factor is, therefore, very short, unless indeed oil vaporization is continuously proceeding between the hot surface of the piston and the cylinder wall.* On the other hand, continuous burning is or should be confined to the working stroke; very little carbon, therefore, should be formed. On this point Mr. Veitch Wilson, Chief of the Lubricating Oil Department, Price's Patent Candle Co., on 9 September, wrote to the author: "The question as to what we may attribute the tendency of gas-engine oil to carbonise is an exceedingly difficult one, and suggests a prior question, viz., whether the carbon found in gas-engines proceeds from the fuel (gas, oil or petrol) or from the lubricant. From data before me, supplied by the authorities already referred to, I think that I am correct in saying that, in the case of a gas-engine, the relations of gas and of lubricating oil used, gas being reduced to actual weight in accordance with its known specific gravity, are about 96 to 97 per cent. of gas against the balance in lubricating oil. Analysis shows that the composition of town gas, or of gases from mineral oil or from spirit, closely approximate one another, viz., hydrogen, say 16 per cent., carbon about 84 per cent.; and, on this assumption, it seems not unfair to suppose that the bulk of the carbonaceous deposits which are found in gas and oil-engines is due to the fuel rather than to the lubricant." If this view is correct,

* "We are of opinion that, owing to the complex nature of all hydro-carbon oils, to which this test (evaporation) applies, the liberation of the lighter and more volatile fractions begins and may proceed at temperatures much lower than that at which the volume of the liberated gas renders it visible to the most acute perception, or sufficient to affect the most delicate instruments."—"Some Aspects of Lubrication," by J. Veitch Wilson, page 29.

lubricating oil, as it undoubtedly flashes during the explosion stroke, might also occasionally do so during the compression stroke, without betraying the fact by any material increase of carbon deposit.

The arguments that ascribe premature ignition to the flashing or burning of the lubricant, might be countered by ascribing it to incandescent carbon in the cylinder or ports. It is quite possible that this also may be a cause of pre-ignition. But it does not fully meet the case. As incandescence would be continuous, it should also lead to continuous pre-ignition; it should make pre-ignition independent of the amount of lubricant used, but the reverse is the case; it should confine premature explosion to cases where such deposit is present, but this is not in accordance with fact.

Speaking with the reserve due to imperfect study of the problem, the author inclines to think that low-flash lubricants are a cause of premature charge-firing. The easiest way out of the difficulty, therefore, would be to use only oils of the highest obtainable flash point. Unfortunately the oils of this description now on the market are extremely viscid. This gives rise to two fresh difficulties: one, the feeding of such oils into the cylinder; the other, the spreading or dispersion of the lubricant within the cylinder. The first difficulty could be overcome by a mechanically-operated lubricator, such as Messrs. Snowdon use for their "Sinol," a graphitic lubricant of high viscosity. The second is thus described by Mr. Case: "An oil fed into steam is blown, by the velocity of the steam, into minute particles, which are carried through all the steam and deposited on all surfaces with which it comes in contact. In a petrol engine a drop of oil entering the cylinder remains almost intact, and oils of as high flash point (585° and 640° F.) and viscosity (234″ @ 210° and 320″ @ 210°) as 'Hecla' and 'Extra Hecla' will not spread over the surfaces." Both Messrs. Bluman and Stern and Messrs. Snowdon are inclined to differ from this view; the managing director of the former writing: "I am of opinion that by the combustion in the cylinder, the lubricating oil is spread in somewhat similar manner to the process going on in a steam cylinder"; that of the latter stating: "Any good oil, as 'Sinol,' is diffused or sprayed all over the cylinder." The fact, however, that

inventions * have been patented with a view to overcoming the difficulty mentioned by Mr. Case, rather points to its recognised existence, at least in the case of the more viscid oils.

As the author would, no doubt, be asked why in gas-engines oils with 400° to 450° F. flash-point do not cause premature ignition of the charge, he may at once say that he has not studied the question. Very possibly, the cylinder temperature being kept lower and the quantity of the lubricant used being much more accurately determined, decomposition is sufficiently impeded. Again, it would appear as if hydro-carbon vapour exerted an influence on lubricants which a gas mixture does not. On 28 August, Messrs. Crossley Brothers wrote to the author: "Some short time after we had commenced manufacturing oil-engines, it was brought home to us that the class of oil suitable for lubricating a gas-engine piston would not do so for an oil-engine, as there appeared to be more tendency for the oil to carbonise and to cause the rings in the piston to stick."

The practical conclusions to which the author arrives are, first, petrol motors should be fitted with positive feed-lubricators, ensuring a sufficient, and no more than sufficient, oil supply; second, that with such lubricators high flash point oils should be used in preference to the oils now commonly employed. The high viscosity of such oils is favourable to the retention of compression; on the other hand, it tends to increase friction and thus also the temperature to the rubbing surfaces.

Conclusion.—The author has endeavoured to bring the present technique of motor-car manufacture briefly before the Members of this Institution, because the industry is undoubtedly one of growing importance, and because there are so many features that admit of improvement, and so many points that require the elucidation which

* E.g. Patent, No. 20,449$^{\underline{96}}$, D. Smith. The inventor proposes to introduce the lubricant with the air-charge. Patent No. 5,147$^{\underline{97}}$, S. Rolfe. During the working stroke, immediately after explosion, water together with lubricant is injected into the cylinder.

the Members of this Institution are pre-eminently qualified to give. The majority of manufacturers do not possess large financial resources, nor much available time for the technical research and experiment needed for the advancement of the industry. In some cases, alas, they do not seem to recognise the importance, nor the real economy of dealing with the problems before them, in a scientific manner. Time and money, spent on independent research, on obtaining expert advice on testing, analysing and so on, represents to them expenditure of capital, better employed elsewhere; whereas, there cannot be a shadow of a doubt that, properly applied, time and money so spent are the most rigid and comprehensive economy that a manufacturing business can effect.

But it is not only to the Members individually but to the Institution as such this subject is presented. From the former, opinions and information are solicited; to the latter is submitted the question, whether considering the magnitude of the industry, the Council of this Institution might not, in accordance with the practice and scope of our association, afford the same assistance as they have given to the gas-engine industry. A Gas-Engine Research Committee has been formed; could not the scope of this Committee be extended to the investigation of the many problems surrounding and impeding the progress of the petrol engine?

The author begs to thank correspondents for information, and publishers for the loan of illustrations, courteously accorded.

The Paper is illustrated by Plates 78 and 79 and 25 Figs. in the letterpress, and is accompanied by 2 Appendices.

APPENDIX I.

Effect of admitting Aqueous Vapour to the Fuel.

Patent No. 14,242$^{\underline{95}}$, J. H. Ladd, is for the manufacture of gas by charging air first with hydro-carbon vapour, and then with water vapour. The specification claims that such gas is very advantageous for use in explosion engines, not only because it is cheap, but also because it produces more power than coal gas, and its combustion is so perfect that no deposit is found in the cylinder.

Patent No. 10,018$^{\underline{96}}$, H. Lane, states:—"The utilization of heavy oils . . . in oil-engines has hitherto been attended with considerable difficulty, the combustion being imperfect . . . My invention consists in the construction of an apparatus . . . whereby I alter the nature of petroleum and the like, by decomposing it in a retort along with water, or along with gas-engine products, viz., steam or aqueous vapour and carbonic acid . . . in the one case, producing a mixture of hydrogen and carbonic oxide, and in the other case, carbonic oxide alone. Neither hydrogen nor carbonic oxide gases, when undergoing combustion, give off smoke or smell, and both gases are permanent or free from condensation when in a cold state. These qualifications, which are not possessed by petroleum and the like, when vaporized are of very great value for actuating gas-engines, as the combustion of hydrogen and of carbonic oxide gas is more easy and perfect, and causes no deposit in the cylinder."

In his Paper, "Liquid Fuel for Steamships," read before this Institution, July 1902, Mr. Edwin L. Orde states (page 422):—"Besides this actual loss of heat (viz., in raising the water to boiling point, boiling it, and heating the steam to the gas temperature), the presence of water destroys the conditions necessary for perfect combustion." On the other hand, in "Liquid Fuel: Its Application

Past and Present," a Paper read before the Technical Society of the Pacific Coast, Mr. R. G. Paddock said, "To approach the theoretical limit (of steam generation), vaporization appears to be the most practical plan . . . Vaporization means the combining of the steam and oil, without a residue, in a gas sufficiently stable to enable it to reach the furnace without condensation. Superheated steam appears to be the only medium which will accomplish this. Its action is quite different from saturated steam . . . The temperatures of oil and steam necessary to produce a vapour depends upon the characteristics of the oil."

Whereas Mr. Orde comments on the cooling of the flame, by the addition of water, Mr. Paddock draws attention to the increased temperature by the use of superheated steam. Thus, referring to welding with liquid fuel, he observes, ordinary steam spraying is unsuited, because the dissociation of the oxygen and hydrogen of steam in contact with iron at a red heat, appears to produce oxygen in a nascent state, causing a more rapid oxidation than when liberated from the nitrogen of the air; secondly the flame is subject to chilling. But, if superheated steam is employed, and the oil vaporized, the heat is so intense that iron may be readily melted.

The two views are not incompatible, because Mr. Orde speaks of the influence of water, as such, on the fuel; while Mr. Paddock refers to highly heated steam. It is Mr. Paddock's observations that chiefly interest the oil-motor engineer.

The possible effect of water on the charge lies in its influence for or against the fuel decomposition. With every combustible gas, there is a lower and an upper limit of explosibility in the presence of air. Between these limits the mixture is more or less violently explosive; below and above them it burns quietly or is incombustible. In 1901 Professor H. Bunte * gave a table of limits for twelve gases and vapours. From this the following figures are taken:—

* "Explosive Gas Mixtures;" a Paper read before the German Society of Gas and Water Engineers, 1901.

TABLE 3.

Description of Gas.	Range of Explosibility.
Carbon Monoxide . . .	58·4
Hydrogen	57·0
Water Gas	54·3
Acetylene	49·0
Coal Gas	11·2
Ethylene	10·5
Alcohol	9·7
Methane	6·7
Ether	5·0
Benzene	3·9
Pentane	2·5
Petroleum Spirit . . .	2·5

It will be noticed that, whereas pentane and petroleum spirit have an explosive range of only 2·5, that is to say, between the lower and upper limit (percentages of combustible gas in mixture), there is a difference of only 2·5; the gases that head the list have very much wider ranges. Now, on the assumption of decomposition before or during initial inflammation, an air-detonating gas of narrow explosion limits may be converted to simpler members—hydrogen, ethylene, acetylene, carbon monoxide, etc., with very much wider ranges of explosibility. Whatever, therefore, might be the disposition of these wide range molecules, locally, to the oxygen in the charge, they would necessarily offer conditions more favourable for easy and rapid combustion than the narrow range molecules of undecomposed fuel. Decomposition undoubtedly does take place. Mr. E. L. Orde records it in the flame of liquid fuel-burners; and other writers observe it in the internal-combustion engine. Thus, Mr. J. E. Homans writes: "Among the elements that combine to promote the conditions just specified are certain chemical changes, giving rise to gases of high fire temperature, or causing shrinkage in the proportion of good fuel in the cylinder." * Oil and petrol engine

* "Self-Propelled Vehicles," 1902, page 373.

diagrams also indicate the same fact. The author's suggestion is that, at high temperature and pressure, water vapour, if in minute quantity, as in the case of a leaky cylinder, is at once decomposed, and, by its decomposition, upsets the chemical stability of the fuel, hastening and extending its decomposition. The action of larger quantities of aqueous vapour is not so certain. Possibly by reducing the temperature, they retard and diminish decomposition, thus leading to a more regular and economical combustion of the fuel, with higher mean pressure and more power.

APPENDIX II.

Nickel Steel for Automobile Work.

The author advocates nickel steel, in automobile work, for rivets, pins, exhaust valves, rods, shafts, axles, and springs. In a number of technical journals, British and foreign, the properties of this material have been lately to the fore. Its chief merits are:—(*a*) Stiffness or resistance to deflection under impact, and toughness or resistance to fracture under repeated impact.—Steel with 3 per cent. nickel shows 48 per cent. greater stiffness, and 45 per cent. greater toughness than similar carbon steel. With 5 per cent. nickel the difference is even greater. (*b*) Elastic limit.—The elastic limit of mild and medium hard steel is usually taken as 46 to 50 per cent. of the ultimate strength. With 3 per cent. nickel steel it is stated to be 63 to 74 per cent. (*c*) Tenacity.—In simple carbon steel, a crack once formed quickly develops, and the material breaks short. In nickel steel the rend is gradual. The latter gives warning, the former does not. (*d*) Temper.—Nickel allows a reduction of carbon, makes the steel more sensitive to temper, and facilitates the tempering of irregular shapes. Where a forging is too complicated for oil tempering, the requirement may be met by using a somewhat softer and tougher steel and introducing from 3 to 4 per cent. nickel. (*e*) Resistance to oxidation and heat.—

An 18 per cent. nickel alloy is said to be practically incorrodible. A high nickel alloy also withstands well the action of heat. (*f*) Anti-frictional properties.—The American Sullivan Machine Co.* state:—"We believe that the nickel renders the wearing parts of machines which run on other parts less liable to cut, the nickel apparently having the property of making the surfaces smooth with wear, even though not always properly oiled."

As regards percentages, the Crucible Steel Co. of America recommends a 0·35 carbon 5 per cent. nickel steel for all first class work. The efficiency increase in the material is stated to vary with the amount of carbon present, running from 40 per cent. in soft steel to over 60 per cent. in hard steel, while, in the case of very hard tool steel, the effect is said to be much greater.

Discussion on 17th October 1902.

The PRESIDENT thought the first duty of the members was to accord to Captain Longridge a very hearty vote of thanks for his Paper. The author very justly said in concluding it that the subject was one of very great interest and importance to the country at the present time, and he trusted Captain Longridge would be rewarded for his trouble in writing the Paper by a very full discussion of the numerous points he had raised.

The vote was carried by acclamation.

The PRESIDENT announced that, before the discussion was proceeded with, Captain Longridge desired to make a few remarks on certain leading features to which he especially wished to direct attention.

Captain LONGRIDGE in the first place thanked the Council for affording him the opportunity of bringing the Paper before the members, and secondly, thanked the members present for the cordial interest they had taken in the subject. He desired to emphasise the subject, and not the author, still less his trade connection. He

---

* Quoted in the "Horseless Age," 23 August 1902.

wished the members to abstract from the Paper any association with the last two points, accepting his assurance that in offering it he had absolutely no trade axe to grind. He came before them as an insignificant member of the Institution, offering many facts and a few opinions, and asking advice and guidance in the path of progress. The broad question before them was: In what direction did progress lie? Looking at the facts recorded in the Paper, there appeared many paths leading to the same end. For instance, there was, in the first place, the development of the impulse-every-revolution engine, and secondly, the question of steel cylinders. The "Autocar" of the present week contained a very significant tendential remark, as follows: "The water-jacket seems to be doomed on cycle motors, by the growing practice of boring the cylinders out of steel." It was his belief that, if ever they were to arrive at a jacketless high-powered motor, the use of steel cylinders was the first and necessary step. The importance of the subject led him to hope that opinions would be expressed as to the class of steel best suited to the purpose. Later on he would lay before the members the views of one of the leading English firms, and also the opinion of one of the largest continental firms.

The third important point was the interesting problem of water. If ever high-powered jacketless motors were to be run, some provision would have to be made for the reduction of the internal temperature, and he suggested that possibly the economic solution of that difficulty lay in the use of water. Unconsciously, perhaps, every user of alcohol as fuel was also adopting the use of water.

The fourth point was one which the members might off-hand at once condemn, unless he indicated its close connection with the preceding. In spite of steel cylinders, and in spite of the application of water, a high-powered jacketless motor would certainly involve temperatures at which it would be unsafe to add the fuel, except at the point of ignition. That was one of the reasons why he had raised the query of the expediency of carburetting at the end of the compression stroke.

Fifthly, in the eventuality of which he had spoken, another important point was the adequate lubrication at high temperatures,

(Captain Longridge.)

and he hoped that before the discussion concluded, some gentleman would make a useful suggestion connected with better means of lubrication at such temperatures. Those were some of the paths of progress which appeared to him to be indicated by the facts he had recorded in the Paper; there were a great many more which he would leave the members to indicate and discuss.

With regard to the Paper itself, he was fully impressed with its deficiencies. One of those deficiencies of a practical nature and one of a more theoretical character he wished to make good at the present stage, in order that they might be discussed. A great deal of trouble and expense had arisen from the difficulty of obtaining cast-iron jacketed cylinders free from porosity and blow-holes. The old theory of blow-hole formation in steel and iron castings was based on the percentage of carbon and the casting temperature. But Brinell's researches, illustrated at the Paris International Exhibition and more recently discussed by Axel Wahlberg,* showed that, in steel at least, those factors were of secondary importance. It appeared that the chief causes were the absolute and relative percentages of silicon, manganese, and, in some cases, of aluminium. While it was known that the formation of piping or cavity was the effect of shrinkage during solidification, blow-holes were due to the absorption of gases, chiefly hydrogen, nitrogen, and carbonic oxide, and of the subsequent dissociation and evolution of those gases in the process of cooling. Brinell contended that, by the presence in certain proportions of one or more of the constituents mentioned, that defect could be prevented, and those proportions had been embodied in what were called " density equations." If he (Captain Longridge) were returning to the foundry trade, and re-living the three or four years during which he pondered over the mysteries of the cupola, remembering with gratitude the advice he received from Professor Thomas Turner, the line on which he would work would be the determination of similar density equations for cast-iron. If those were determined, the founder or the manufacturer, by previously arranging his analyses, could rest easy that, with ordinary precautions

* Journal, Iron and Steel Institute, 1902, part I, page 347.

in pattern-making and in founding, his castings would be free from blow-holes. The subject was, he thought, worth the attention of such automobile makers as ran their own foundries.

The other point, of a more theoretical character, referred to cooling. He felt that he ought to have prefaced the section on cooling by some reference to the very valuable experiments made by Professor Burstall on the temperature of the gases to be cooled. On his (the author's) first examination of the figures published in the Second Report of the Gas-Engine Research Committee,* he was struck by the want of uniformity in the temperature fall; there was no gradual curve, and no regular drop, but a very noticeable fluctuation of temperature. A closer investigation, however, disclosed two curious facts, first that the maximum fall of temperature always occurred practically at half-stroke, and secondly that there was a certain periodicity in the fall. It might be remembered that Professor Slaby had previously noticed the half-stroke fall, and attributed it to increased piston-speed. He also appeared to have observed irregular fall, but he (Captain Longridge) had never been able to see that Professor Slaby had traced it to any particular cause. He (the author) suggested the cause to which the irregular temperature fall or periodicity was to be referred was indicated by the following figures:—

Point of Stroke.	Mean Fall in 0° C.
0·2	100°
0·3	70°
0·4	99°
0·5	105°
0·6	58°
0·7	76°
0·8	67°
0·9	52°

The second column represented the mean fall calculated from the eight columns of Professor Burstall's Plate 181 (Proceedings 1901). The figures showed a heavy drop of 100° C. at 0·2 of the stroke, followed by a lower fall of 70°, then an increasing drop, rising from

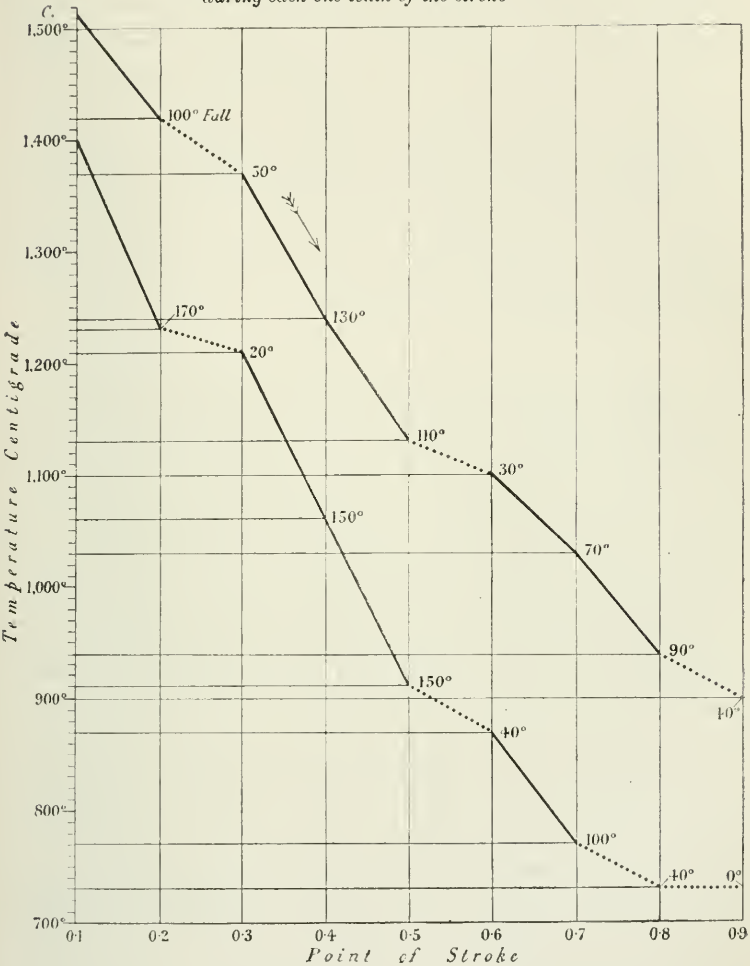
* Proceedings 1902, page 1031.

(Captain Longridge.)
99° to 105° at half-stroke, succeeded by a much lower fall of 58°. Finally there was a further rise to 76° with a succeeding drop of 56°. Something like a wave movement in the temperature fall was distinctly visible. That could be shown far more clearly in the two diagrams, Fig. 29 (page 753), which exhibited the results of certain single experiments. He did not like to argue from single experiments, because they proved his theory much more strongly than the mean results did. This would be seen by comparing the diagrams with the columns of mean figures. As he had argued from the mean results of those experiments, he felt justified in suggesting a theory. His theory was that, when an elastic body, such as air and gas, was exploded within the compression chamber, a series of wave currents was set up, each elastic impact on the walls intensifying the loss of heat by conduction, and each reflex movement lessening its action, irrespective of internal heat changes due to the suppressed expansion and contraction of the gases. According to that theory, it was not to the difference of temperature *per se* between the gases and the walls, but to the intensity and periodicity of the explosion waves that, in the fraction of time occupied by the stroke, the cylinder loss was mainly due. That also explained the lesser heat loss with weak charges, the explosion producing waves of less intensity and frequency; and it also, he thought, explained why in such cases high initial temperature did not lead to perceptibly increased cylinder loss, while, from the point of view of inflammation and combustion, such temperature was advantageous. From that theory it also followed that, at the earlier portion of the stroke, the wall loss largely depended on the explosion wave intensity, while during the later portion of the stroke it mainly depended on the cooling surface area.

Some of the members might think that the Paper did not correspond with the title, and might have expected him to give descriptions of all the leading cars on the market. If he had announced a lecture on Mr. Balfour as Prime Minister of 1902, he thought they would have been disappointed if he had described Mr. Balfour's general appearance, because by buying a sixpenny illustrated society paper the subject would have been far better dealt with than he could have hoped to deal with it in a lecture. But the audience

Fig. 29.

Two Examples of Fall in Temperature of Gases during each one-tenth of the stroke.



(Captain Longridge.)

would expect him to describe his character, to explain the principles of his life, to give his political opinions, their tendency and goal. It was on the same lines that he had treated the subject of the Paper. He did not describe in detail the various cars because, by a very slight expenditure on those excellent publications "The Autocar," "The Motor Car Journal," "The Automotor," and other Papers—to which he was largely indebted for the loan of blocks for the Paper—the audience could by their own fireside have got a far better idea of the appearance of the cars than he could hope to give them in the short time at his disposal. He had endeavoured to group together certain facts and details, sufficient to enable him to point out what he thought were the principles of the construction, and the tendencies of evolution in the petrol motor car.

Professor THOMAS TURNER said he had but few remarks to make in reference to the Paper, because he was interested only in the metallurgical aspect of the matter. He quite agreed with the author as to the entire unsuitability of white hematite iron for cast cylinders. Not only would the metal be very hard and difficult to turn, but it would be extremely brittle, in addition to having the great drawback mentioned by the author, namely, being full of blowholes. The metal suggested (page 676) would, he felt quite sure, always run solid, would be sufficiently soft that it could be easily cut, and would be quite dense and strong enough for all practical purposes. The only point about the analyses, to which he wished to draw attention, was that the silicon should be varied a little according to the thickness of the casting. If the casting ran too hard, a little more silicon should be put in; but if it ran a little softer than was required, the proportion of silicon should be decreased. In reference to the amount of phosphorus mentioned, he had borne in mind the question of price. It was cheaper to use $\frac{3}{4}$ per cent. of phosphorus than $\frac{1}{2}$ per cent., and for all practical purposes they would be about equally good, but the phosphorus should certainly not exceed the amount given in the Paper. It would have been very interesting if the author had said something as to the quality of the steel.

Captain Longridge explained that he thought those who joined in the discussion would speak with greater freedom, if he kept back the opinions of the eminent authorities which he was prepared to quote at the end of the discussion. He would like to hear the opinions of the speakers first, and would then state what were the opinions of those authorities.

Professor Turner said that in reference to steel for cylinders, his opinion was that if the properties desired could be obtained with a low carbon steel, high carbon steel should certainly not be used. In other words, as low a carbon steel should be used as would give the properties desired. These properties were, in the first place, sufficient strength, perfect toughness, with no brittleness whatever, and lastly, good wear. There must be a certain amount of carbon, otherwise the wearing quality was not obtained; but about 15 per cent. of carbon would produce everything that could be desired in a steel for the purpose, if it were found in practice that a steel with so low a percentage of carbon wore well. He was inclined to think this would be the case, and that therefore a higher carbon need not be used.

Mr. Frederick Grover said that the question of the products of combustion had been somewhat freely brought into the Paper. In connection with the experiments made some time ago, the author said (page 673) "Whether these observed facts are due to increased temperature, or to some chemical action is a point open to argument." He thought there were three possible explanations of those experiments. One was that suggested by the author, namely, the increased temperature, the second was the chemical action, and the third was the purely mechanical action due to imperfect diffusion of the gases. It had been thought that the results of those experiments were obtained, purely because the mixture in the region of the sparker was of a high explosive and pure character. Possibly that might have been so, but he thought it was very extraordinary that such an unstable factor as the diffusion of the gases should have produced such concurrent results. He should be pleased to hear other views on that point.

(Mr. Frederick Grover.)

With regard to the diffusion, he had made an experiment which might be of interest and point to some practical value. He put into a cylinder, from the bottom, a flow of coal gas, and sampled the mixture at intervals of about five or ten minutes, both from the bottom and top of the cylinder, to ascertain what the rate of diffusion was. He was much struck to find that it required an hour and thirty-five minutes to produce anything like an even diffusion of the gases. The coal gas lodged immediately under the top cover of the cylinder, and remained there with a very slow rate of diffusion. With regard to the diagram, Fig. 8 (page 697), a few days ago he put an indicator on to a small gas-engine, and having taken out the drum stop of the indicator, he drove it at a high constant speed of rotation in one direction. Then he applied the pencil of the indicator and took a diagram. The point he endeavoured to elucidate was, whether he would get a diagram on the paper anything approaching the diagram Fig. 8 (page 697). He was rather struck to find that, out of a number of diagrams so taken, he obtained several which exactly corresponded to the one he had drawn attention to.

He wished to draw the author's attention to two points. One was that he said (page 697) "That a hydro-carbon, even without the presence of water, would in the combustion chamber decompose into light and heavy constituents, seems very probable." In the experiments to which reference was made, water would have been present. Water was present in the cylinder, because the cylinder was filled with water first, the products of combustion and the charges then being measured in by measuring out known volumes of water, so that the cylinder would be damp. But in the case of the gas-engine to which he had just referred, the compression was somewhere about 80 to 100 lbs. to the square inch, and the cylinder would be hot and dry. There were several other points to which he would like to refer, but he was anxious to hear the more practical remarks of the other speakers.

Mr. George Iden said that, to many of the members who still considered that the motor-car was not a branch of mechanical engineering worthy of their time and attention, some remarks as to its

performance would have been particularly interesting, and might possibly have been an inducement to them to make further enquiries and to take a greater interest in what had, up to the present, been the experience of anyone connected with the industry, namely, that the cars were in their performances particularly fascinating, and provided a means of exhilarating and healthful enjoyment. Turning to the Paper, the first point of which was the type of motor, he, as one of the pioneers of the industry, could offer his testimony to the assistance the horizontal motor lent to the designer in constructing a car on the most beautiful lines. He adhered to that type for three years after the Act was passed in England, but the experience on the Continent, and the successes obtained by the vertical type of motor were so great that he sacrificed elegance for utility, and adopted it; and he had since found that the advantages of the vertical type of motor over the horizontal were very much greater than he had formerly considered they were, in that respect differing from the author. He had no desire whatever to go back to the horizontal type.

With regard to the explosion-between-two-piston motor, he did not consider that it was a suitable motor to put in the hands of the inexperienced public, at all events not in its present stage, as its parts were far too complicated. He had endeavoured to design and make his own motor cars as simple as possible, because it must be remembered that they were not placed in the hands of mechanical engineers. Motor-car manufacturers had to cater for a public with a non-mechanical mind, and he considered that the necessary complications of the explosion-between-two-piston motors were too great for the handling of the general public.

With regard to the impulse-every-revolution motor, one system of which the author had stated he had recently patented, no one would watch the progress of that motor with more interest than himself; in the same way, there would be no one more ready to take advantage of any improvements in that respect brought forward by any manufacturer. It would be of very great assistance to motor-car manufacturers, if more mechanical engineers could be induced to take such an interest in the subject, that English manufacturers

(Mr. George Iden.)
would be enabled to compete with their continental neighbours in many of the spheres of manufacture to which the author had alluded. The one great difficulty he had found in the impulse-every-revolution motor was that the exhaust valves could not stand the rapidity of the discharge. That brought him to the subject of the next point, namely, the material and methods of manufacture; it was the material of which the exhaust valves were made which had such a vast controlling influence on the sustained power of the high-speed motor, which he had adopted in preference to the former slow-working type. Whereas formerly his motors ran at a normal speed of 720 revolutions per minute, their normal speed was now 900, 1,250 and 2,000. Those speeds he could and did accelerate up to 1,250, 1,500 and 3,000 respectively, the latter being air-cooled. At the same time the speed could be reduced, and the motor run at 150 revolutions per minute. The motors were all working on the Otto cycle principle. It would be readily understood that if an impulse-every-revolution was given to motors working at such high speeds, the exhaust-valves had a very severe strain put upon them which, he thought, steel would not stand. He had tried steel of all kinds, with varying percentages of carbon, and had found it impossible to get a steel exhaust-valve to stand with the high-speed explosion motor. Nickel steel, with varying percentages of nickel, he had also tried, but he had not found anything, either for air or water-cooled motors, which gave the same power or had the same life as pure nickel. He was now using nickel exclusively, with the very best results; it did not deteriorate, and did not stick in the seating or the guides. In a motor fitted with a nickel valve the power would be sustained, whereas if it were taken out and a steel valve substituted the motor immediately began to lose its power. The nickel valves lasted more than ten times the length of time that the steel ones did.

As to the material for cylinders and water-jackets, the author's remarks with regard to the trouble in the foundry, with the design of water-jacketed cylinders in cast-iron, could not be disputed, but by careful attention to the proportions and to the stays or brackets or bosses which connected the one with the other,

the trouble could be very considerably minimised. Moreover, while the cast-iron must be sufficiently fluid to run into the various intricate and complicated parts of the casting, a degree of hardness could be obtained, still allowing the metal to be sufficiently fluid, which would give a splendid result in working for the walls of the cylinder. His percentage of failures since he began to cast cylinders in the foundry that he had installed for motor-car work had not reached one per cent., while the failures in the castings which he obtained some three years ago from several different foundries varied from 15 to 60 per cent. He mentioned that to show the success which could be achieved by close attention to what, to the uninitiated, might appear very trifling matters, allowing for the expansion and contraction, the bracketing of the water-jacket to the cylinder walls, and by so proportioning it as to get the best results. His cylinders were now all cast with solid heads and cast-iron water-jackets; and although he claimed to be among the first who adopted a light, separate water-jacket, having made the first one in 1897, he abandoned it on account of its complications, the slightest failure in the pump-supply causing a distortion of the steel cylinder. However, perhaps he did not have the proper percentage of carbon in the steel. His steel cylinders were made out of solid-drawn tubes, such as were supplied by various tube-drawing firms in Birmingham, and he did not have the material analysed to ascertain the percentage of carbon.

Lubrication was a very important point in steel cylinders, and he had so much trouble in that respect, that he was very glad to abandon steel and resort to cast-iron cylinders, from which he had had most excellent results.

With regard to carburettors, the author rather challenged the carburettors now being used for the controlling of the motor. He (Mr. Iden) had found many defects in the carburettor and naturally set about to improve it, and had every reason to be satisfied with what was being used at the present time. After running some motors with this new control arrangement, about ten times the distance run with motors with the ordinary inspiration carburettor, and governed on the exhaust, he had found the cylinders were in a very much

(Mr. George Iden.)

better condition; the piston-rings and the cylinders were not clogged, and everything was in first-class order. The motors were run under exactly the same conditions, using the same lubricating oil. He had patented the arrangement he had mentioned, whereby the cylinders could be thoroughly scavenged, while preserving at the same time the vacuum in the vapour-supply pipe. Immediately the governor closed, or partially closed, the supply valve, it admitted a supply of air from the atmosphere immediately above the induction valves, first weakening the mixture and then closing it altogether, while at the same time it allowed the required volume of air to go through the cylinder, cleaning and scavenging on its passage through to the exhaust pipe.

As one of the pioneers of the industry, he wished to tender his thanks to the author for bringing the subject forward, and for the very able manner in which he had dealt with it, as he felt it was quite time that more of the members of the Institution should interest themselves in what was proving to be one of the most promising industries in the world, and in which it would take but a very short time, at the rate of progress now being made, before more capital was invested in it than in railways. He appealed to those members present who were manufacturers to devote their time and attention to supplying motor-car manufacturers with many parts of the cars, which at present they had been unable to obtain in England. That was particularly the case with springs. He had tried a great number of springs of English makers, and regretted to say that he could not obtain springs from them giving so much satisfaction as those he obtained on the Continent. That was a matter of very great regret. He was very reluctant indeed to go to the Continent for springs, but the failure of English makers to give him a reliable article compelled him to go there for them. He put some English springs on cars which, after they had been on the road with passengers not more than two days, assumed a permanent deflection. He took the springs off, sent them back to the makers, and asked them if they could not provide something better. It was exceedingly expensive to put fresh springs on, to get his blacksmith to temper another plate and to put it in and strengthen it up. At the same

time he knew that the springs were more than strong enough to carry the load which he had designed the motor car to carry. He went to the Continent, ordered a spring of a lighter section than the one he had designed, and he found it carried a heavier load, was more resilient and never took a permanent deflection of more than $\frac{1}{8}$ to $\frac{1}{4}$ inch on a 3-foot spring. He appealed to those who were interested in that industry to see to it whether they could not beat the continental makers in that respect. Without wishing to take any honour for himself, he could say that the motor-car designers in England had, within a very short time, already wrested some of the laurels from the Continent, and hoped to wrest still more. The English makers could now hold their own, and hoped shortly to be able to supply the Continent instead of the Continent supplying them.

With respect to electric ignition, neither accumulators nor coils—particularly the latter—could be obtained in England, until quite recently, as satisfactory as those that could be obtained on the Continent. The one he was now using was of French make that would give over 3,000 vibrations per minute, without failing. This was the Guinet-Carpentier design, and he was given to understand that it was now being made in England. Until the English electricians could succeed in getting over 3,000 vibrations per minute, these coils were useless for the high-speed motors for cars.

The double-acting compound brake that he applied two years ago was working quite satisfactorily, and left nothing to be desired.

Discussion on 31*st October* 1902.

Mr. W. Worby Beaumont said he thought all members must thank Captain Longridge for his Paper, and although all might not agree with him in everything he said, one could certainly sympathise with him in some of his aspirations. His Paper was on Oil Motor Cars of 1902, and in order to take the wind out of one's sails with regard to the badness of the title, the author said something at the previous Meeting about some one who was to lecture upon Mr. Balfour, and

(Mr. W. Worby Beaumont.)

who took a great deal of time in describing his hat or his boots (page 752). He, Mr. Beaumont, thought some of the members would have liked to have heard, as well as the opinions with regard to Mr. Balfour as the motor, something about the hat and the boots as the motor car.

Turning to the motor, the first part of Captain Longridge's Paper dealt with what one must call suggestions with regard to the construction of a motor, such as he thought might possibly secure several things which had not at present been arrived at, that which he aimed at most being an approach to the equal turning possible to attain with a steam-engine as compared with the internal-combustion engine. In attempting to arrive at that, the author had made a great many remarks on forms of gas-engines which had been made, forms which had been proposed, and forms which had been experimented with to a very considerable extent, though none of them had survived the experimental stage.

In the early part of the Paper, however, the author made remarks with regard to the vertical *versus* the horizontal engine, and pointed out that in America by far the larger proportion of the engines used were of the horizontal form (page 670), and he thought that Europe was likely to follow suit. In this country and in France he, Mr. Beaumont, thought one might admit that there was something of the nature of fashion on that point; at all events, there did not seem to be any reason why, so far as the engine alone was concerned, the horizontal engine should not perform as well as the vertical engine, which was by far the most popular. As one well knew, the horizontal form in oil-engines and gas-engines was almost universal, so far as the construction in England was concerned, and also he might say a large proportion of those in France. But the vertical form had in recent months almost become the favourite with those who were constructing the higher speed engines for motor cars. In the motor vehicle, however, it really did not seem so much a question of the one or the other, as a question of convenience of working the engine in to suit the construction, not only of the motor but of gearing and numerous other things which had to be considered in working out a design—

the complete design. He did not think Captain Longridge would be followed in the expectation that Europe would follow suit; because convenience as to construction and access for a large proportion of all the high-speed long-distance vehicles likely to be made would still indicate that the vertical form was the more likely to be generally used.

For small powers or for larger powers it might be found, especially on very long non-stop full-power runs, that cylinder lubrication, with present knowledge, would be more certain with the vertical than with the horizontal engine; but this objection, if it existed, was certainly of no importance, for horizontal engines ran perfectly well, and the lubrication could be and was completely satisfactory for all ordinary lengths of run. When the horizontal engine lent itself to suitable arrangements of gearing and of car, dictated more or less by questions other than simply choice of vertical or horizontal position, there were no valid objections to the latter.

When the author spoke of the motor itself, of the arrangements with regard to valve-gear, and as to certain things which would secure more economical results, one could not help feeling that those matters must be considered not simply with reference to the most economical engine, but with reference to the application of the engine. In many cases it would be better to use the simplest possible form, though not the most economical. It would be not only better, but it was almost impossible, to use any of the other more complicated forms of engines until one came to the larger powers. As far as one could see at present, it certainly did appear that for the smaller powers some loss in economy for great gain in simplicity would be the consideration which would settle the selection of the particular engine. But when one came to the form of engine which it might be assumed Captain Longridge proposed, one found an absence of drawings, and one was compelled to admit that, so far as the outline description was concerned, there did not appear to be any noteworthy departure from the designs of numerous gas- and oil-engine inventors. In fact, Captain Longridge himself referred to numerous designs, which had approached more or less to that which he seemed to describe in his outline. It seemed a pity

(Mr. W. Worby Beaumont.)
that the author had not thought it worth while to supply some drawing, even though they might be only diagrams, showing the sort of engine which he proposed to take the place of all the others that were at present running. Briefly, Captain Longridge proposed one of what might be called the displacer engines; in other words, he proposed to use the front or the outer end of the cylinder—that which was usually open—as an air-pump, and to pass the air which he received and compressed, to a small extent, round to the working end of the cylinder of the other half of his engine. The author said that he must in that necessarily leave a certain amount of the residue of the combustion during the previous stroke; and he then proceeded to find a virtue in necessity, and quoted certain experiments to show that remnant gases might not only produce no harm, but in some cases might be really useful. Captain Longridge quoted certain experiments. It might happen with regard to a particular engine speed and compression, that conditions could be obtained which might usefully, or without loss, employ a certain amount of residue in the cylinder; or at all events one might be careless as to the completeness with which those burnt gases were swept out. But surely all recent experience and experiments, on what might be called a commercial scale, had shown that the more completely the residuum was swept out by one or other of the several means now successfully used, the more economical was the working of the engine ; and the best results had been obtained when the residuum had been swept out not by separate pumps and other complications, but swept out as far as possible without any of those. For instance, there were those described some time since by Mr. Atkinson, and some others who followed in the discussion of Mr. Dugald Clerk's Paper.*

Coming to the next point, one must admit that the greater number of impulses, which Captain Longridge proposed to obtain, was extremely desirable. He did not say the author would not be able to arrive at it—he thought it likely that ultimately he might—but

---

* Proceedings, Institution of Civil Engineers, 1895–96, vol. cxxiv, page 101 *et seq.*

at present at all events one had to consider the practical motor and vehicle, the whole combination. They could have four-cylinder motors with very little, if any, more complication than a motor with two cylinders on the arrangements such as those proposed. The question arose as to which, after all, was the better: the four-cylinder engine, or the two-cylinder engine with an equal number of impulses and the arrangements which have been described. One could run a four-cylinder engine with four or three of its cylinders, with two or even one of its cylinders working. With the arrangements proposed, one might happen upon those very conditions which ordinarily would prevent two out of all four of the cylinders working, and these conditions might put one or both of the author's two cylinders with the compressor or displacer out of operation. So that, taken with what was known to be the little things which happened occasionally with ignition arrangements, valves, valve tappets, springs, etc., it was questionable at present whether the simple form of four-cylinder engine would not be preferable to the two-cylinder engine with the displacer and pump arrangements, especially as one had not yet got the engine which Captain Longridge proposed, and as one did know that the results of numerous experiments, with not only oil-engines but with gas-engines, had not been encouraging in that particular direction. In speaking of gas-engines, he began with his own experience, which went back to 1870, when he was engaged in the construction of the Lenoir gas-engine, and he had more or less followed out such matters from that time; and he took some interest in motor vehicles. Therefore it might be assumed that he was interested in finding anything which would really be an improvement. It was not mere adverse criticism on the Paper which led him to attempt to point out some of the conclusions which one was likely to arrive at, after reading what the author had written.

After dealing with his suggestions with regard to the engine, the author said (page 674), "In the matter of piston speed, this year's engines show a general return to the earlier speeds given by 700 to 800 revolutions per minute normal running." That was on a point which affected the loss of powers, and the possible or probable occasional difficulties with these motors, but it was not a question of

(Mr. W. Worby Beaumont.)

piston speed; the trouble was the number of times that the direction of motion of the piston was changed, or, in other words, the number of revolutions per minute. If one could use a higher piston-speed to get down to the lower revolutions per minute without any disadvantages, a good deal could be accomplished; but, as Captain Longridge pointed out, a lower speed meant a larger cylinder, more weight, and so forth. From that the author was led to questions of construction of the cylinder. He referred to the steel cylinder and the light jacket, and in fact pointed to various constructions which had been adopted, not alone by those he mentioned, but by others. He believed Mr. Roots was one of the first to use such a thin cover for a jacket, and Colonel Holden was earlier than the name mentioned. Then there was Pennington who also used steel cylinders, and found a thin jacket was useful. He, Mr. Beaumont, did not think any of the makers of cylinders, either for oil-engines or for gas-engines, had ever tried to use white hematite in the foundry for casting them. As far as he himself knew, white hematite might be very useful for making puddle-bars or for making castings for malleable ironwork, but unless one was ready to see them go to pieces like glass, and produced by very costly processes, he did not think white hematite was likely to be of very much use.

There were several parts of the Paper in which the author touched upon questions, which had not formerly been but were now fully appreciated by a great many makers. For instance, the author referred (page 681) to the position selected for the valves. Not only did one find the valves occasionally placed so that the cutting and the side pressures to which he referred obtained, but one found also that the arrangements of the exhaust and the admission ports were even worse than he suggested in two or three parts of the Paper; but recent makers did not commit these errors.

There were many points to which he would like to refer, among other things as to cars, but as the Paper was chiefly upon motors, and there was really very little said about cars, and especially as the President had announced that several gentlemen were expected to speak on the matter, he would shortly conclude his remarks. The author (page 690), speaking of the motor, thought that on the whole,

"for petrol at least, a good deal more stress is laid on pre-mixing than need be, and that carburation at the end of the stroke, inasmuch as it admits the use of higher compressions and has another important advantage, is probably as good if not better and more economical than the more ordinary method." That was after other remarks with regard to compression, and the defects which were assumed with regard to the existing motor. It was not quite true to say that, with the arrangement referred to on the page quoted, a higher compression within a range of useful compression could be obtained better by the author than by others commonly used. In fact, at the present time very high compression pressures were being used, and in ordinary working the temperatures were not sufficient to bring about early or pre-ignition, while for all ordinary working the use of the now universal electrical arrangements for ignition made it almost impossible that the period of ignition should be any trouble whatever. He might certainly say that, with the most recent engines, there was no trouble whatever in that direction. For the motor car, practical questions of a different order dictated more or less a limit to compression.

With regard to the formation of either a gas or a vapour, the author would be interested if he consulted not only those authorities whom he had quoted, but also the specifications of Smyer, 1885, and of Dr. Schiltz, 1885, who pointed out,* though he was too early for the modern development of the oil- and gas-engine, that the finely-made spray was more easily combustible than the oil gas. Schiltz not only pointed that out, but also why it was, and gave illustrations of his methods of arriving at a practical result. In conclusion, he expressed his regret that Captain Longridge had not taken more advantage of the position to which he referred in the company in which he was interested, and told the members something more about Oil Motor Cars of 1902.

Mr. E. J. Chambers wished to add his meed of praise to the author for his very able and suggestive Paper. If he himself were

* "Motor Vehicles and Motors," pages 321–327.

(Mr. E. J. Chambers.)

a manufacturer of motor cars—and he was seriously thinking of taking the subject up—he would be very grateful for what Captain Longridge had written. He thoroughly endorsed the idea thrown out by the author, that the Council in its wisdom might appoint a Committee, which it was quite possible might run on all fours with the Gas-Engine Research Committee, to inquire into the powers of explosive mixtures for motor cars. But that Committee must be particularly careful not to trespass on the field now legitimately occupied by the manufacturers of cars and engineers in general; and it must also be very careful, for fear of bringing a hornet's nest around its ears, not to pass judgment on the multitudinous suggestions as to design and materials made by various makers. It seemed to him that there was a great likelihood of the question of motor cars getting, if not on to the wrong line, at any rate on to a main line, without any idea that there were any sidings. As a matter of fact, the travelling public wanted two kinds of cars. One was what he should call the "car de luxe," which was guaranteed to go at a very much greater speed than by law established. That seemed to be the idea of a great many of their friends who were very wealthy. Such cars cost anything above £400. If he might hazard a guess—no doubt he would be put right by the motor-cars manufacturers who were present in large numbers—the building of those cars was not very remunerative, at any rate very big dividends were not declared by the companies that were building them, and he was looking for those dividends.

But there was another kind of car, which was absolutely wanted in very large numbers for doctors and for business men. Such cars were required to run 5, 10, 15, or 20 miles a day in town or country, and at a speed not exceeding 12 or 14 miles an hour on the level. The car must be a simple one, which should not cost more than £200 or £250, nor weigh more than 12 to 14 or 15 cwts., carry two people with a bit of luggage, or three people without the luggage, and that would not get out of order about every 25 minutes. Such a car would find a large sale in this country. It must also be remembered that such a car needed standardizing. It must not be built in the haphazard sort of way that many motor-car makers were building

their cars at the present time. It seemed to him that some of the motor-car builders built their cars in order to sell their spare parts. He paid £14 the other day for a spare part, and he had to send the money before he could get it, although his credit was pretty good in the Midlands. He was glad to say that when the spare part arrived, it fitted and worked, but £14 for a spare part was too much. Another spare part having gone wrong, he wrote asking its price. The manufacturers were a long time in answering, but eventually wrote saying the part was 50*s*. Meanwhile, wanting to use the car, he started it without the spare part, and it had gone better ever since. It was one of two valves—a magnificent thing—regulating the flow of the petrol to the burners. He got rid of it, and attached an ordinary pipe from the little stop-tap arrangement, and it went all right. Within three minutes of the time that he walked up to the car and struck a match, he could back the car out and start on his journey.

He had not used electric ignition yet, but he was told it was a very good thing. A friend of his said to him, "I have electric ignition; you ought to have it too." He ascertained that it cost £25. The next time he saw his friend he inquired how the car was going, and his friend replied that he would not advise him to bother with the electric ignition. The car he had in view ought to be built at a cost of not more than £200 or £250, and should be built on the latest plans. Motor-car makers should make the car as simple as they could; they must not bother about Captain Longridge and other gentlemen who were settling in their minds which was the theoretically best engine. As the last speaker had said, it was not always the most economical engine that was the best suited for a motor-car. The car should be run day and night for three months to settle that it was the right kind of car to build. Then 500 of such cars should be put down and built right away, and nobody should be allowed to have one of the cars until the 500 were completed. When that number had been disposed of then the manufacturer could start with his next series of 500. If the cars were not standardized and if the spare parts were not sold at a reasonable price, the motor-car manufacturers would richly deserve what a great many of their friends

(Mr. E. J. Chambers.)

already obtained when they did not deserve it, namely, the gibes and sneers of American and German engineers because they were "back numbers." English motor-car manufacturers knew how to build cars, and there was an enormous demand for such cars, but the users must be given some confidence in them. He hoped the Council would not only look after legislation with regard to motor cars, but look after the development of the science of the cars. While the makers were making engines for present-day use, and while they were preventing the horses starving while the grass was growing, the manufacturers would be getting ready for the next 500 series.

Professor F. W. Burstall said the remarks he had to offer were not those of a motor-car expert. He might almost say with the last speaker that he was getting shy of being considered as a motor-car expert. That generally meant his friends asking him to go out for rides with them, and if anything went wrong he was expected to put it straight in a moment, and that was not altogether easy if the car happened to be badly broken down. Mr. Beaumont's statement, that a practically perfect electric ignition had been obtained, had struck him as being very remarkable. He himself did a good deal of motor-car work, and whenever anything went wrong he always looked to the igniter, and in about 70 per cent. of the cases he found it was the igniter that was giving the trouble. He did not say that there were not certain cars—there were several—in which it was very rare to get trouble with the igniter, but at best it was a troublesome thing. He had had a good many years' experience of igniters for gas-engines, and knew they required very careful watching. Those makers in this country who were putting on electric igniters for large power gas-engines put the igniters in duplicate; one could be drawn while the engine was running, and repaired and put back again while the second igniter was in use. If the system were perfect, it followed as a matter of course that twin igniters would not be provided. They gave a considerable amount of trouble. With regard to the best form, he thought there was no doubt that the magneto, that is, a revolving armature free from batteries of any kind and producing what he might call a short, stout spark which was as necessary for

the petrol motor as for any other. The coil, worked with a few secondary batteries, was not altogether satisfactory; it would probably ignite 95 per cent. of the charges, leaving the remaining 5 per cent. unignited. That of course was a matter of very small importance; in motor cars it did not matter if a few charges missed ignition, unless a hill was being climbed. The subject of ignition needed to be very carefully considered, and if it could be dispensed with he thought it was worth a good deal of trouble to do it. The author had proposed a certain cycle engine, in which he intended as far as possible to effect the ignition by either hot surfaces, which he (Professor Burstall) thought was a very good plan, such as in the Hornsby engine, or by another system which was just coming into use in this country in another form—the Diesel method. The objection to the Diesel method, in the form in which it at present existed, arose from the enormously high compression that had to be used. When working with heavy oils, Diesel, in order to explode his charge spontaneously, had to compress to 600 lbs. per square inch. Probably with petrol the compression might be halved, but then it would be 300 or 200. He did not know, and as far as he knew nobody knew, very much about petrol and its actual working. He thought probably Professor Robinson would be able to say more about that subject than he (Professor Burstall) could, because Professor Robinson had experimented to a considerable extent with petrol in oil-engines.

He liked the engines the author mentioned very well in all but one detail, namely, the question of keeping a proportion of the exhaust product to mix with the incoming charge. Mr. Beaumont very rightly said that experience had shown that that was bad from an economy point of view, but he did not state why it was bad. The reason as far as he could see—and he believed it was admitted—was that a sufficient volume of charge coming into the cylinder was not obtained. If there was a half cylinder full of exhaust product and they proceeded to draw in air, quite apart from the jet of petrol that would be involved, the heat of the exhaust product heated up the air, and a very small weight of air was obtained in the cylinder, and that they did not want to get. For economy in any kind of internal-

(Professor F. W. Burstall.)
combustion engine, it was necessary to follow out the arrangement of the original inventor of the so-called Otto cycle, that is, the maximum weight of charge in a given volume of cylinder, and to do that the temperature of the cylinder and the temperature of the drawn-in air must be kept as low as possible. For that reason there was no doubt that the cylinder walls, the piston, and every part must, if possible, be kept cool.

Experience in gas-engines had shown the necessity for water-jacketing the piston, and for using a positive scavenger charge. He did not mean by that, some method of scavenging which was independent of a pump or some such form, but a positive scavenger charge such as several of the large gas-engine makers were now putting in. The Westinghouse Co. were putting it in their new 3,000 H.P. engine that was being built at Pittsburg, and a number of other makers were putting in similar contrivances. The effect of the scavenger charge was not to get rid of the burnt products because they were injurious to themselves, but because they were hot. For that reason he very much feared that Captain Longridge's engines would not be specially economical. Whether that was a matter of importance or not he did not know. If it was not important—and he should think it was not of great importance—then the engine would be very successful.

He ventured to suggest, however, that there was another alternative which gas-engine makers also were beginning to view with a favourable eye, namely, the introduction of the double action. It had not proved very successful until recently, but now there were several large engines running which were double acting, and he did not see why the little quick-revolution engine should not run double acting, and if any trouble arose with the bearings the principle of forced lubrication could be adopted, if it was worth trying. Double action would give an impulse per revolution on the Otto cycle. He was cordially with Captain Longridge in his remarks as to the design of the average motor used for motor cars; they did not seem to him to be designed in the best possible way. No doubt there were difficulties of space, weight and other things, but living as he did in one of the centres of motor manufacturing, he was often struck with

the extraordinary trouble which some makers took to provide elaborate castings and elaborate machining, all of which was extremely expensive. The simple forms of steel tubes, light valves, and so on, could all be adopted, and while of course he did not pretend to wish to teach motor-car manufacturers their business, because no doubt they knew it better than he did, the cars seemed very complicated in the matter of mechanical details.

One other point might be of importance, namely, the growing tendency on the part of gas-engine makers to put their valves in the back end, that is, to use a flat cover, and to work the valves in that. Not very long ago in the Institution he was called to order on that point by some gas-engine makers,* who said it was utterly impracticable, but it was now the standard design for engines above 500 H.P. by the best firm of gas-engine makers in the country. He knew the design was extremely good. He had seen a 750-H.P. engine running with it, and had been shown the drawings of a 1,500-H.P. engine with the valves in the back. He thought the motor-car people might bear in mind that they might simplify their admission and exhaust valves by placing them in the covers, an arrangement which was of course essential in a double-acting engine.

The subject of fuel was one on which he would like to say a few words. It was worth considering whether petrol was the best material, and whether alcohol was not really a better substance for driving oil-engines. Dealing with the question of oil-engines, it must be noticed that in all petrol and oil motors, the ratio of the mean pressure to the maximum was much smaller than it was with gas-engines. That was an extremely difficult thing to understand, and he confessed he had puzzled over it, and tried to account for it in several ways. If one took an oil-engine having a compression of 70 and a maximum of 250 lbs., a mean pressure of something like 60 lbs. would probably be obtained, whereas if it was gas with exactly the same amount of heat poured into the cylinder, instead of 60, most likely 85 or 90 lbs. would be obtained. The probable reason he thought was due to a fact, which he had never obtained in a gas-

* Proceedings 1901, page 1132.

(Professor F. W. Burstall.)
engine, namely, that the oil was not entirely burnt. He was afraid that in all oil-engines the atomised jet of oil only partially burned or that only some of its constituents burned. Petroleum or alcohol, or any such substances, were formed of complex hydro-carbons. Some of those hydro-carbons might burn at once; others might burn later, and apparently a good many of them did not burn at all, but passed out unburned into the exhaust. That was probably one explanation of the lack of efficiency of oil-engines as compared with gas-engines.

Turning to the Diesel motor, which was very interesting as bearing on Captain Longridge's own work, Diesel obtained a thermal efficiency, that is, the ratio of the heat of the oil to the horse-power of his engine, of about 38 per cent.—it was a little more with the larger engines—with a compression of 600 lbs. The engine at present holding the record, one of the Premier Co.'s engines, obtained with a compression of 105 lbs. a thermal efficiency of 38 per cent. The reason Diesel obtained such a high efficiency was simply because of his enormous compression, and not necessarily that he burnt the whole of his oil completely. In conclusion, he wished to congratulate the author on having produced a Paper dealing with the motor-car subject and its motors all round, and he thought such a Paper could only do good by making them all think of the numerous improvements that still remained to be made.

Mr. Charles T. Crowden said he feared he had little to say on the matter, as Mr. Beaumont and several other speakers had anticipated some of the remarks he had intended to make. To deal with the subject of motor cars in one Paper, as Captain Longridge had tried to do, appeared to him to be attempting to cover far too wide a field for one Paper, particularly as it dealt with not only motors, but also gearing and carriage-building. To his, Mr. Crowden's, mind it was quite a simple matter for any ordinary engineer to construct a high-speed motor, whether it be steam, oil, or electric, and any capable engineer could construct a transmission gear, but few engineers, unless they had had some experience in carriage-building could design suitable motor vehicles. Few engineers had experience

in wheels, axles, and springs, and most of them, if they had been railway engineers, introduced horn plates and axle-boxes into their designs. To construct a motor carriage as a whole, the motor, gearing, and the carriage work, making it into a successful machine, became a very difficult problem to solve, although individually each engine, gearing, and carriage, could be made successfully independent of the other. In a motor carriage not only did one require rigidity, but also a great deal of flexibility. If the carriage were made too rigid, then, in passing over unevennesses of the road, the machine bearings bound and made going hard, and altogether rendered the carriage very unsuccessful. One required rather more to imitate the American practice of locomotive building, and to make the engines flexible, more like a basket, so that they would take up inequalities of the road without binding the bearings. Carriage-builders were of very little or no assistance to the motor engineer, except in the case of making the bodies, and he was afraid that in a few years the assistance of the carriage-builder for motors would not be required at all, because bodies would soon be made entirely of metal, and there would scarcely be any woodwork at all about the motor car. In the case of petrol cars one heard of fires, so that the less woodwork was put into them the better in that respect. Carriage-builders in their art were practically at a standstill; they had made little or no advance during the last forty or fifty years. Most of the carriage-builders of today would state that it was impossible to make an axle-box to interchange from one axle arm to the other. Only a short time ago he visited a large axle works in the Midlands, the proprietors of which professed to be the best people and the largest firm in the trade. Yet not one of their axle-boxes would interchange with one another. In the carriage trade scarcely any advantage had been taken of the use of mild steel, and the axle arms were turned in rude lathes, usually by boys, and they were far from being round after they were turned. The axles were then case-hardened, and the chilled box was let on by a process of grinding with emery, the boxes being marked to each individual axle-arm; if one did not know, the right wheel could not be made to fit any but the right carriage axle-arm.

(Mr. Charles T. Crowden.)

Great trouble had been experienced in this country by motor-car builders in getting springs and axles, and consequently a large quantity were being imported from France and Belgium. One was constantly told that proper springs and axles for motor work could not be obtained in this country, even at the present time. He feared that the axles and arms now supplied in this country for motor cars were not well enough made, or at all events, not for that particular work.

He agreed with the author that, unless the motor cylinders were water-cooled, they would not be satisfactory; air-cooled cylinders were not suitable for motor-car work, unless the cylinder and head had a water-jacket. Moreover, not only did an internal-combustion engine require a water-jacket, but it also required the piston to be water-jacketed as well. No doubt the head of the piston, while the motor was running, was in a state of incandescence, and caused a great number of back explosions and irregularities, which were not understood when they happened. He considered that motors making 400 to 600 revolutions per minute were far more satisfactory than engines of higher speeds. Mr. Iden spoke of motor engines running 3,000 and 4,000 revolutions per minute with air-cooled cylinders (page 758), and the only difficulty he had with those motors was that the exhaust valves would not stand. He said he had also tried every metal available, and yet the exhaust valve burnt out and would not last. He was of opinion that such engines could not be much improved; they might be suitable for such things as Santos Dumont's airships, but were unsuited at present for motor-car work. With regard to double-acting engines, such as the Atkinson and the Koch, &c., having two pistons working in one cylinder, the moving parts of those engines were usually so heavy that they could not be well balanced, and they were not suitable for high speeds, although the advantage of using one sparking plug and one set of valves was greatly in their favour.

With regard to the question as to whether the engines of motor cars should be vertical or horizontal, he had constructed many cars having engines fitted both ways, and, if anything, he preferred the horizontal one, especially when the engine was constructed at an

equal distance from the centre line of the car; that is, taking the centre line of the frame, the engine was not poked into one corner, but placed with the fly-wheel on the centre line, the engine revolving in the same direction in which the car travelled. If one took a light cycle wheel in one's hand, and made a few revolutions with it, and while revolving attempted to divert it from its vertical or horizontal path, one found a great deal of resistance. He found that by putting a fly-wheel in the centre and working at 800 or 900 revolutions, that it steadied the car and it could be steered with a hand tiller-rod, even when going at very high speeds, and it was almost impossible to throw the car over. Most makers, especially

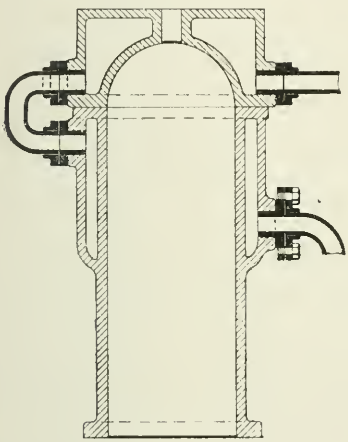


Fig. 30.
Cylinder Head and Cylinder showing independent Water Circulation.

those using horizontal engines, put the engine in one corner of the frame and the gearing in another, and consequently the whole motor car wobbled about sideways. For very light motors he had used for many years steel-tube cylinders with very great success. But for steel cylinders he had always used cast-iron pistons and cast-iron rings; and he had also tried phosphor-bronze rings with success. The steel cylinders were provided with a water-jacket in rather a novel manner, Fig. 30. He placed the cylinder into the water tank which formed a ready jacket. The valve-box was bolted to the back of the cylinder with a scraped joint, and there were separate pipes

(Mr. Charles T. Crowden.)

connecting the water-jacket of the valve-box to the tank, and the whole thing circulated itself by its own heat, the pump circulating water through the condenser only. Under that system it was impossible for any water to leak into the cylinders. The same system could be introduced in the case of cast cylinders and water-jackets. Cast cylinders were much more easily made this way, and were less costly for renewal. The system of independent water-cooling of the heads was patented by him many years ago, and had been since copied by many other makers.

With regard to transmission gear for large cars, the system of the differential countershaft and side chains was to be preferred to a differential main axle. The use of gear wheels and friction clutches was very costly, both in up-keep and in first cost; and he thought a belt with fast-and-loose pulley made a very cheap friction clutch, and seemed to be more efficient than many of the so-called friction clutches which were advertised. If belts were fitted to a car with proper tools, using a fast-and-loose pulley with Dick belts, no trouble whatever would be caused by the wet. Such machines would work with more efficiency than the present cars fitted with the Panhard or other types of gear. Captain Longridge referred to injecting water into the motor cylinder (page 715), and he, Mr. Crowden, wished to point out that that was tried many years ago by Louis Simon, of Nottingham, who attempted to utilize the heat that was lost due to the water-jacket. He considered that lamp-ignition was a most dangerous method, and the apparatus for it ought to be taken off any car fitted with it at the present time. In the event of an accident it was very liable to fire the whole car, while with electric ignition there was very little danger on that score. He much preferred the high-tension spark, with coil and batteries to the low-tension spark with internal contact-breaker. A few weeks ago he had had a bitter experience with that type of sparking on an engine which was burning ordinary petroleum.

Professor William Robinson wished to join in thanking Captain Longridge for his elaborate and suggestive Paper, dealing with a great many points of importance to all interested in oil motor cars.

He thought it was teeming with questions for discussion, but time would only allow him to touch upon a few outstanding points on oil-motors. He agreed with the author when he advocated positive feed, which gave the means of exact measurement and control of the charge.

On page 691 the author mentioned the lack of information regarding explosions of petrol mixtures. He (Professor Robinson) quoted from his recent work * experiments that Mr. E. C. Oliver had carried out, and gave the results and diagrams showing the pressures obtained by the explosion of various mixtures of gasoline and air at constant volume in a cylinder. Records were also given of the time of explosion and the cooling effect of mixtures with and without residual products of combustion. These showed clearly that lower explosion pressures were produced with residuum present than with a fresh pure mixture. Dilution of the charge with burnt products reduced the maximum pressure, and retarded the inflammation and cooling. There was one remarkable point about the curves, which indicated that, as the compression of the mixtures before ignition was increased from about 30 up to 65 lbs. on the square inch, the maximum explosion pressure of a mixture that contained residuum rose more rapidly, but was lower than that of the pure charge.

He thought the author would agree that such results were certainly more applicable to oil motors than those from coal-gas quoted in the Paper (page 673). In the latter the mixtures of coal-gas and air were measured and fired over water in a wet cylinder, which must have taken up a considerable part of the heat of combustion, and undoubtedly had an effect upon the resulting pressure, in fact made the conditions quite different from those that obtained in a practical engine. Water gave trouble in a gas-engine cylinder. Besides, some of the results and conclusions (page 673) did not agree with the best gas-engine practice, which showed that higher pressures were obtained with pure charges than when these were diluted with residual products.

* "Gas and Petroleum Engines," 2nd Edition, 1902, page 910.

(Professor William Robinson.)

The action of water was different in the petroleum engine. He had tried in a 10-brake H.P. Priestman engine the injection of a few drops of water with each charge into the combustion chamber. The hard metallic knock or sound heard with the explosion at full load was immediately reduced to an occasional dull thud. Then the engine ran steadier, cooler, and gave more satisfactory results with American Royal Daylight petroleum. However, above a certain limit too much water in the cylinder caused irregular and unreliable ignition by the electric spark, which in fact soon failed to fire the charge, so that the engine eventually stopped. Water was not a fuel, but by absorbing heat and forming vapour gave a more uniform pressure throughout the explosion stroke.

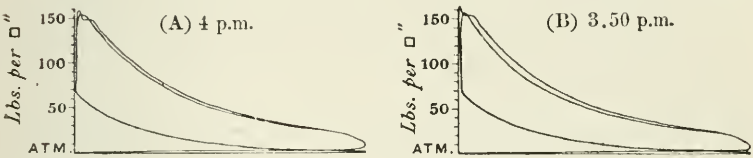
He had read with surprise (page 737) that the author doubted the possibility of the automatic ignition of a petrol mixture under any temperature attainable in a water-cooled motor. He tested the question again by an experiment with a 5-brake H.P. Hornsby-Akroyd water-cooled engine, having the vaporiser also partially water-cooled and adjusted to work on Russolene. The engine had been running steadily and well in the forenoon on Russolene. Without making any adjustment or alteration whatever, the supply pipe was simply joined to a vessel containing petrol of specific gravity 0·680 obtained from Messrs. Carless, Capel and Leonnard. The vaporiser was heated in the ordinary way by a coil lamp for ten or twelve minutes, and the engine was started quite easily. A load was put on the brake wheel, and the heating lamp removed for a preliminary run of about an hour. The engine was allowed to cool down during the dinner hour, and the vaporiser was heated again in the afternoon. He then made a trial of an hour on the brake. The engine ran steadily at 200 revolutions per minute, and the indicator diagrams (A) and (B), Fig. 31 (page 781), taken every five minutes showed that compression of the petrol mixture to 70 lbs. per square inch produced regular automatic ignition of the charge, giving an explosion pressure of about 160 lbs. per square inch. With compression of 65 to 68 lbs. per square inch the automatic ignition was somewhat retarded, diagram (C), but steadily improved as a greater load was applied by the brake, and the heavier charges admitted gave higher compression.

Fig. 31.

Indicator Diagrams from a 5-Brake H.P. Hornsby-Akroyd Water-cooled Engine giving 4·4 I.H.P. and 3·63 Brake H.P. on Petrol by Automatic Ignition.

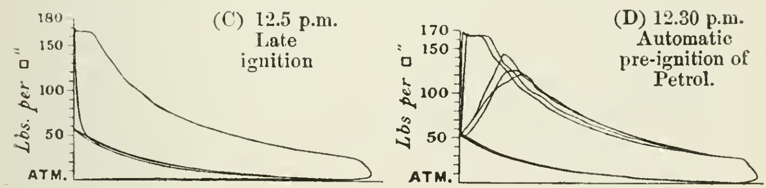
Tests on 29 Oct. 1902.

Revs. per min. 200. Net brake load 45 lbs.



Tests on 31 Oct. 1902.

Revs. per min. 240. Net brake load 30 lbs.



In this engine the piston came quite close to the end of the cylinder, and there was a narrow neck communicating with the vaporiser which was partially water-cooled, so that it was difficult to see even the remotest possibility of the lubricant passing into the vaporiser. The petrol was fired automatically and regularly. As a matter of fact, he could easily get pre-ignitions at a lower pressure by simply changing the speed or the load, so that the automatic

(Professor William Robinson.)

ignition of petrol by compression alone against a metal surface was easy enough. The vaporiser was comparatively cool and remained dark, much below red-heat. Its temperature was only kept up by the explosions, since no heat was applied from the outside and the coil lamp was removed at the start. That day he had tried a higher speed, 240 revolutions per minute, and less load on the brake with similar satisfactory results. When the governor cut out a charge the next one was heavier than usual, and the diagram, D (page 781), indicated automatic pre-ignition. Still earlier ignition during the compression stroke was produced in this way, while no change was made in the ordinary lubricant of the cylinder which was kept cool by the circulating water in the jacket.

In these trials the engine was not working under the best conditions for petrol. Benzoline and gasoline required higher compression and gave more power than Russolene by automatic ignition in this engine, whilst the piston kept clean and well lubricated. This engine also worked on alcohol in France. Automatic ignition depended on the nature of the fuel, and not on the lubricant as stated in the Paper.

Again, regularity of automatic ignition, as well as efficiency in working, depended on the piston speed. It also appeared from experience that both the power and efficiency increased with the speed up to certain limits, which varied with the fuel or combustible used, the compression of the charge, cooling action of the walls, and the size of the cylinder. The most economical speed in petroleum engines varied from about 450 to 700 feet per minute, and in the gas-engine up to 800 and 1000 feet per minute. That was apart from the question of durability; he was simply speaking of efficiency.

The limiting temperature of the cylinder walls for maximum efficiency was usually higher than that for maximum power. In a petrol motor the efficiency and economy continued to increase while the temperature of the water-jacket was raised even above the boiling-point, although there was a marked falling-off in the power of the engine due to the smaller weight of each charge admitted. On the other hand, when the cylinder of the petroleum engine was

just hot enough, about 400° F., not to interfere with the lubrication by thinning the lubricant, nor to tighten the piston, every additional increment of temperature lowered the efficiency. There was thus a connection in the petroleum engine between the power really got out, the piston speed, the compression of charge, mean temperature of cylinder, cooling surface, and a number of other points.

He quite agreed with the practical conclusions of the author regarding the use of high flash-point lubricating oils in the motors, because of the desirability and possibility, in small motors at any rate, of using air-cooling and dispensing with the troublesome water-jacket. Already petrol motors for cycles and light motor-cars were working successfully without a water-jacket, and were kept sufficiently cool by conducting away the heat through the metal frame by increasing the cooling surface and using fans in some cases. Air was such a poor conductor of heat, and had small capacity for heat, that it made air-cooling inefficient. A compromise was possible for the sake of convenience. According to the present practice with the imperfect internal-combustion engine, it appeared necessary for good continuous lubrication and steady running, to reject and conduct away the heat that could not be converted into work in the cylinder. The water-jacket was still necessary for larger engines in which it was impossible to get the heat away fast enough from the cylinder by other means, to prevent pre-ignition of the incoming charge, and so that the heavy lubricating oils should suffer little or no loss by evaporation at the mean temperature of the cylinder walls.

Mr. Herbert Austin said that the last time he spoke at the Institution* he drew attention to the fact, that it was very difficult to arrive at any reasonable result by discussing so extensive a Paper in such a short time. That equally applied to the present occasion. It was a great pity that this should be so, because the subject was a very interesting one. He was sorry to notice that most of the discussion had been quite irrelevant to the title of the Paper,

* Proceedings 1901, page 318.

(Mr. Herbert Austin.)

although in his opinion the title was a wrong one. He had come to the meeting in the hope of hearing something about motor cars. Although the discussion had been interesting, and, no doubt, very good, he could not say that so far he had learned much about motor cars. A better title for the Paper would have been "Motors," because the reference to cars outside of the motor itself was very short.

He was pleased to note that the author seemed to think that the horizontal engine would become the most popular style of motor, but he did not think it was possible to say which was going to be the most satisfactory motor, or which was the most satisfactory position in which to put a motor, because this depended on the system of transmission. That was the difficulty with motor cars. There was no difficulty with the motor. If everything connected with motor cars was as satisfactory as the motor of today, he was sure the cars would be a great deal more satisfactory than they were. Once a perfect system of transmission was obtained, the motor would have to be made to suit the system. Good motors could be made either way; he did not know that the advantages obtained from the one system were not quite as good as the advantages obtained with the other. In a note at the bottom of page 670 the author said: "The multiple cylinder motor costs more to make; uses more fuel and lubricant for the same amount of work; and requires more attention and more repairs, since there are more parts." One of the first motors he built for a car was a single-cylinder double-piston type. He only tried it once and then put it on the scrap heap, and wished he had put the drawings on the scrap heap before he made the motor. Instead of there being less parts, there were far more. The double-piston type of motor seemed to mislead people into thinking that there was only one cylinder. There were two, because each piston must move the distance of its stroke, and there must be either three connecting-rods or two fly-wheels and two crank-shafts. The maker had the choice of the two. It might be done in some other way of which he was not yet aware. He did not know where the economy came in, if there were two ordinary cylinders, two connecting-rods, one crank-shaft, and one fly-wheel.

He had been rather surprised to hear some speakers, and also the author, speak in favour of using mild steel for liners of cylinders. He had always been given to understand that in order to stop wear, or to provide against wear, a material must be used with plenty of carbon in it. He had never heard that it was possible to get into mild steel tubing an equal amount of carbon that could be got into cast-iron. Anyone who had had to scrape the slides of an old pattern Crossley gas-engine would bear him out, when he said that it was very difficult to get under the skin of the slide; it had a far better and harder surface than it was possible to get with any kind of mild steel tubing, even although it was hardened.

He quite agreed with the author in his objection to the solid-headed cylinder. That touched on a point which he thought was very often overlooked, namely, that when a cylinder was ground out, when it was cold it might be perfectly round, but when it got hot, it was quite a question as to whether it was anything like the same shape. In a high-speed motor everything depended on getting the piston and the rings to fit the liner; that was the most important part about the motor. If there was a leaky piston, there was great inefficiency. He did not think it was possible in casting a solid-headed piston to get the cylinder round. If it could be tested, he thought it would be found very much out of round when it got hot; it would get into various shapes dependent on the different degrees of heat.

A remark was made (page 679) in reference to the setting of the valves. One of the first engines that he designed was fitted with a mechanically operated air-valve, which he thought would be a much better arrangement. His experience up to that time had been based mostly on fixed gas-engines. He found, however, there was a great deal of difficulty in getting the air-valve to close at the right time. It did not seem to matter much when the valve was opened, because it could be opened after the piston had gone some distance along its stroke, but it must be closed at the right time. If it were closed a little after the piston had started to return, great difficulties would be encountered. The same would occur if the air-valve was opened a little before the piston got to the end of its

(Mr. Herbert Austin.)

exhaust stroke; exhaust gases would get into the carburettor and that would be rather a dangerous thing under certain conditions. "Popping in the carburettor," as it was understood in the trade, was obtained quite enough without letting the exhaust gases into it. He found that, although much more efficient results might be obtained by fitting a mechanically operated air-valve, it was a great deal simpler to use an ordinary suction-valve. In his practice he had tried ordinary steel valves, nickel steel valves, and cast-iron valves, and his experience showed there was nothing to equal a cast-iron

Fig. 32.

Method of fixing cast-iron head to steel shank of valve.

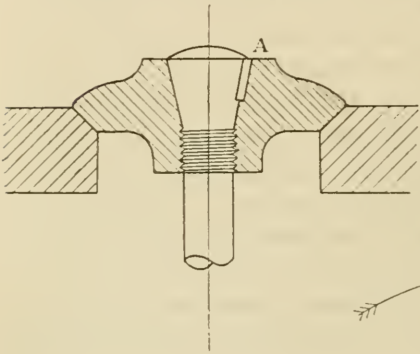
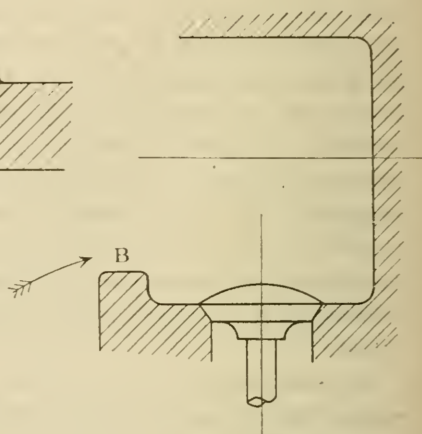


Fig. 33.

Baffle Plate in front of valve.



valve, cast-iron head, with a steel shank, but the iron must be very close grained and preferably cast on a chill. He had no trouble whatever with the heads breaking off the shank. It seemed a very difficult matter to put the head on in the right way, but there was a way in which it could be done quite easily, Fig. 32. A, was the head of the valve in cast-iron. It was better to cast it on a chill, because it was much denser and harder. The difficult thing was to get the right taper. The thread must be a very good fit, and when the head was being put on, it must be made bright red hot. It must

be placed on quickly and jammed up as hard as possible. After that was done a little pin was put in between the two parts, and if that were done properly, the head would never come off. In his engines he had proved that the difficulty mentioned by the author with regard to the scoring of the valves on the one side nearest the piston did occur, but it depended a great deal on the shape of the engine and the size of the port how much difficulty in that respect was obtained. In the plan shown, Fig. 4 (page 683), he thought it would be better to lower the valve into a recess, but not nearly so much as was shown in the drawing. In his later practice he put a sort of baffle plate in front of the valve, Fig. 33 (page 786). A little baffle plate was placed at B, in order to stop the gases, which came in the direction shown by the arrow, from rushing past and scoring that part of the face of the valve.

In reading through the Paper, he was rather surprised to see that the Wolseley motor and car were so very seldom mentioned. He did not wish to draw attention to that fact with any feeling, but in many cases credit had been given to makers of several kinds of motors and cars, which he thought really belonged to the Wolseley. The practice of using an aluminium jacket, for instance, and putting in a cast-iron liner was essentially Wolseley practice; they had never made one in any other way. He thought, perhaps, a maker could lay claim to a system much better, when he could say that he had never made his motor in any other way, than if he said he had experimented with it in the days before some of them were born. The author (page 685) advised the makers to use large valves. That was very good advice. Up to a certain point he did not think the valves could be too large, but it was very difficult to fix a limit, and he did not think taking measurements of the size and stroke of the piston and the size of the valve could be much of a guide, because a very great deal depended on the shape of the inside of the cylinder. If it had a narrow port to go through, perhaps a much larger valve would be required.

Before concluding his remarks he would like to make a suggestion, namely, that it might be a better plan after the Paper was sent round to the members to ask them to write their remarks.

(Mr. Herbert Austin.)

The remarks, after they were sent in, might be viséd by a Committee of the Council; those which were irrelevant might be struck out, and those which were considered to be advantageous might be read, either by the member himself or by the Secretary. He thought better results would follow from that procedure than from the course at present adopted.

Objection was made (page 692) to what was called the crude system of using the ordinary jet carburettor. No doubt it was inefficient, but it was very simple, and, as the Yankee said, "it gets there." For the present state of the trade, at any rate, he thought the less experimenting was done the better. The author said (page 703): "As regards accumulators, the author's experience is that they never run nearly the mileage claimed, and are otherwise troublesome." He was afraid that anybody who had done much experimenting in motor cars would find that, of all the systems of ignition, the accumulator with the high-tension spark and the sparking plug was the most satisfactory of the lot. He could not go into the reasons why, because it would fill a Paper almost as long as the one being discussed. In dealing with cylinder cooling (page 715), the author remarked that for security the system ought to provide for a forced flow of water, and also take advantage of the natural circulation. He wished to make a claim for the horizontal motor in that respect. If the motor was put at the lowest part of the water system, and if there was pump on that system as low as it was possible to get it, with the water tank and the radiators above the engine, whatever little water there was, it was in the motor, and that was the part it was wanted in. If the pump failed, there was natural circulation to fall back on, and he knew from experience that that was some advantage. That could not be obtained with a vertical motor. The remark was made (page 723) that "In most cars the application of the foot-brake withdraws the clutch; and in the Mercedes Simplex of the Constatt Daimler Co., the withdrawal of the clutch automatically reduces the speed of the motor." That was one of the things that he thought ought to be considered Wolseley practice. His company had fought against complication right from the start, and had tried to run a

petrol motor car as a steam car was run, that is, to make the motor as flexible as a steam-engine. For that reason they had endeavoured to do without a governor, and had connected the foot-throttle to the brake-pedal. Difficulty would be experienced if the foot-throttle were connected to the clutch, because the first part of the motion on the clutch-pedal would be to slow down the motor, and then to withdraw the clutch. When it came to be put in again, the clutch would go in first, with the result that probably the motor would stop before the motion could be completed to allow the choke-valve to open. If it were placed on the brake-pedal, that difficulty was not experienced.

Mr. Anthony G. New said that in 1896 and 1897 he had had some little experience with steel cylinders for small explosion-engines, and built several engines in which they were employed. First of all, solid-drawn steel tubes, screwed into cast heads, were tried, but considerable difficulty was experienced in avoiding leakage through the joint. The tubes appeared to warp when they got hot, and were far from satisfactory. He then got one of the large small-arms companies to make the necessary dies, and to supply cylinders in which the head was stamped out in one piece with the entire cylinder. All difficulties of leakage were in that way got over, but the cost of construction, owing to the amount of machine work involved, and the difficulty of water-jacketing the whole of the combustion chamber, were found to be drawbacks. Some samples of the cylinders were exhibited at the meeting for the inspection of those members who were interested in seeing them. Some of the engines had been used for considerable periods, and, with cast-iron piston-rings, they worked extremely well, the cylinder wall becoming beautifully polished and smooth in use, resembling a gun barrel. He was inclined to think that even greater care in ensuring good lubrication was necessary, partly because there were none of those pores in the metal which, with cast-iron, appeared to retain particles of oil. He had no doubt that steel cylinders were preferable for racing cars, where cost was a secondary consideration, and where they were in the hands of expert drivers, but, from a commercial

(Mr. Anthony G. New.)

point of view, the present form of casting had much in its favour. It would be of great assistance to the automobile industry, if some of the large foundries in this country would make a much closer study of cylinder castings of that particular kind. He had found very much better castings in America for cylinders for explosion engines, although out there the explosion engine was far behind such engines in this country.

Whilst quite agreeing with Captain Longridge that flexibility of output (irrespective of speed) was highly desirable in automobile engines, and that this was probably the direction in which improvement might be expected in the future, yet he drew two conclusions from which he himself ventured to differ. The first of these concerned the substitution of the two-stroke cycle for the Otto cycle; the second was his method of rendering the engine flexible. He could not see that, on general principles, an automobile engine having an impulse every revolution could ever be really superior to to one working on the Otto cycle, because the limit of output in both cases was determined rather by the minimum time necessary for the several operations (forming the cycle) to be performed, than by any mechanical considerations. The number of impulses per minute determined the relative power to size and weight, and this was limited by the time required for the several operations to take place. The mechanical speed of any explosion engine was, at present, limited (in practice) only by piston speed, because no other mechanical time limitations were reached before those imposed by the operations themselves came into play. The question of piston speed was of course only a matter of proportionate length of stroke, and could therefore be kept well within safe limits. For this reason the four-cycle engine should be as light for its power as the two-stroke engine, and it was immaterial that its normal speed was double. If the length of stroke were one-half that of the two-stroke engine, the piston speed in both cases would be identical, and the rate of expansion and of compression would be the same in the two cases; the cylinder of the former would, of course, have twice the piston area. Considering the better chances which were apparently given by the Otto cycle for the operations forming the cycle to be

performed accurately, such an engine would appear to be superior to the other type. For automobile work particularly, the reduction of height, which accompanied a shortening of stroke, was a further advantage, and the reduced surface area of the combustion chamber walls appeared to be a benefit also, from a heat economy standpoint. On the question of proportionate length of stroke in an explosion engine, some makers in the past appeared to have had an idea that a longer stroke was accompanied by a greater expansion of the burning gases. This was of course (in an ordinary engine) a fallacy, for the degree of expansion must be the same in all cases, provided that the compression was carried to the same point. Another reason why the Otto cycle appeared likely to hold its own in the future was that any such scheme as Captain Longridge proposed, for improving two-stroke engines, would probably be equally applicable to four-stroke engines, if they were not already as effective in such a respect.

On the subject of rendering an engine more flexible than it now was, he thought that a high output for weight was of even more importance than economy in fuel consumption, and that (in Captain Longridge's own engine) output was unduly sacrificed in order to increase the fuel efficiency. Reduction of weight could of course be obtained in one of three ways: more impulses per minute, a higher mean pressure, or increased volume of explosive charge. In this engine the volume of the charge was reduced, and it seemed reasonable to assume that the number of impulses per minute would also be reduced. It was true that the initial pressure of explosion might be greater, owing to the higher compression employed, but this could not be expected to compensate for loss in the other respects. The reason why he thought the number of impulses would be reduced was because it seemed probable that the operations of complete admixture and of ignition would take longer to perform. He would suggest that a more likely direction in which to look for improvements in flexibility in the future was in variation of the volume of the explosive charge, with means for maintaining the degree of compression constant.

Mr. C. Rainey wished to direct his remarks to experiments with water-injection, which were undertaken at the author's suggestion, and were referred to in the Paper (page 693). His experimental motor was at the time fitted with apparatus for another purpose, which greatly hampered the investigation, and prevented exact conclusions being arrived at. He was greatly astonished at the softening influence of the water-injection. He also noticed that the water in the water-jacket did not heat up as it had done previously, and he therefore emptied the water-jacket. At the end of a twenty-minutes' run the motor was not overheated, in fact he could keep his hand upon the combustion chamber. The increase of power was also most decided. He hoped shortly to continue those experiments, and would be pleased to communicate the results of them later on.

Another point to which he wished to direct attention was that of premature ignition. In a correspondence with the author, the subject of premature firing came up, and he suggested that the cause was attributable to the use of a low-flash lubricant. Of that, however, he was not convinced, and therefore he tried the following experiments. First, he filled the crank-chamber with a low-flash oil, until the crank-pins were covered. Then he removed the cylinder oil-cups and fed with an oil-can, but was unable to get premature ignition. Secondly, while the motor was still hot he removed the induction valves, and inserted about two ounces of lubricating oil upon one of the pistons. The reason he put the oil on only one piston was to enable comparisons to be made between the two combustion-chambers. He then ran the motor, freely using the oil-can; but even under those conditions the results were as before. In the next experiment he emptied the water-tank, leaving only the water-jacket filled. On the top of the combustion-chamber, and of course separated from it by the water-jacket, he put some of the same lubricating oil, and then, with the same copious lubrication, started the motor. The water soon boiled away, but he still kept the motor running until it became so hot that the oil which he had put on the outside of the combustion chamber began to vaporise; but he was still unable to obtain premature ignition. Those experiments were carried out with both

tube and electric ignition, on a two-cylinder Daimler motor, bolted to a concrete foundation, and running at about 1,000 revolutions per minute. There was no doubt that the lubricant did flash, as was clearly indicated by a subsequent inspection of the combustion-chamber, but it must have flashed at the same time as the petrol charge. Although those experiments would tend to show that premature firing was not caused by the flashing of the lubricant, still they were not conclusive, inasmuch as if the same tests were carried out upon another motor the results might be very different. Personally, he was inclined to think there were two causes of premature ignition. Firstly, the platinum points of the ignition plug became red hot in consequence of the heat of the explosions, resulting in the firing of the incoming charge. Upon that subject he was carrying out some experiments, but they were not yet far enough advanced to enable him to make any definite statement. The second cause was the bad construction of combustion-chambers. In order to make connection between the combustion-chamber and the sparking plug, most makers cast a small port or tube through the water-jacket, a sparking plug being screwed into the outer end. Similar ports were also used for the valves, and it was from those ports that he believed the trouble arose. In such small ports or pipes combustion did not take place as quickly as in large chambers, a small flame lingering in them which fired the incoming charge. It might be said that, if such were the case, the firing would become automatic, and undoubtedly that would be so if the tube or port were made of a correct size. The speed of the motor kept constant, and of high velocity. The varying of the petrol charge also had an influence on the lingering flame. Having eliminated those ports from his motor, he believed that that fact, and the additional one that he did not use platinum points to his sparking plug, might have been the reason for his failure to bring about premature ignition from the lubricating oil.

As an illustration of the slow combustion of a petrol charge in small tubes, one might take a piece of $\frac{3}{8}$-inch gas-barrel about 6 feet long, fill the tube with petrol vapour and air, and apply a match to one end. It would then be found that combustion did not

(Mr. C. Rainey.)

occur instantaneously, but travelled slowly along the pipe, occupying from one to two seconds, according to the richness of the charge. With the object of putting his theory to the test, he carried out the following experiment. A piece of small tubing was bent into a semi-circle, fastened in the combustion chamber, and the motor was started running. It went very well at a speed of about 500 revolutions per minute, but immediately he increased the speed there was a great deal of spitting and spluttering. It would be most interesting and instructive to hear the views of the makers of motors who did not use those ports, and he hoped, if any were present, they would relate their experiences, so that one might learn how to settle that vexed question. The author advised (page 746) the use of lubricating oils of a higher flash point, and consequently of greater viscosity, but there seemed to be much diversity of opinion as to whether so viscid an oil would spread well over the cylinder walls. Many elaborate devices had been designed which were intended to effect that purpose. His opinion was that there was no need for any further controversy on the point. One could use the most viscid oils and be certain of their spreading properly, if only the user would follow the suggestion of the author (page 736), and use water with the oil in the crank chamber. He had tried it, and he advised others to do likewise; and if others were as pleased with the results as he was, they would, with him, be thankful to the author for his valuable Paper.

Mr. A. R. SENNETT said he would like to mention a point or two in connection with the motor. He regretted the author's modesty, which prevented him from supplying a drawing of his motor, because he had followed the description as carefully as he could, but without being able to detect any novelty in it. In fact it might be interesting to mention, that the very first petrol carriage run in this country had a motor exactly similar to that described by the author. He referred to the motor made by Mr. Edward Butler in 1884, which was run in 1885, and was shown on Plate 80. That had an extra long cylinder, the front of it being closed; it had a stuffing box, and it passed quasi-compressed air to the back of the cylinder, in

exactly the way the author pointed out. He, Mr. Sennett, took the opportunity of writing to Mr. Butler since the last meeting, and asking him if there was any mistake in that statement. Mr. Butler replied that it was perfectly correct, and he remarked that if one was going to pass compressed air to the back of the cylinder, unless there was an entirely different system of valves, they would be knocked to pieces in a few hours. As members probably knew, the way Mr. Butler got over that trouble was by the invention of his very ingenious circular valve, Fig. 39, Plate 80, which went round at a slow speed, half the speed of the engine. He agreed with what Mr. Austin said (page 784), namely, that engines of that nature really ran into far more parts than a simple engine. But what was worse still was that the engine was a tremendously long one, and a crosshead was necessary, and there were many other objections which he had not now time to touch upon.

He was much interested in the remarks respecting the effect of aqueous vapour in bringing about chemical combination at high temperatures. He would only briefly touch upon the matter, merely in the hope that it would induce other experimenters to follow on in the matter, because he was convinced that there was a great deal in it. He would narrate how it had been so forcibly impressed upon him. Some years ago he undertook a long series of experiments with the object of preventing the formation of smoke in steam and other boiler furnaces, and he found that if one put in oxygen—fresh air—tremendously in excess of the theoretical requirements, one did not prevent the formation of smoke; but if one injected steam it had a most extraordinary and instantaneous effect. The quantity of steam used was rather serious, and after making a cataract and using various timing contrivances for admitting automatically the steam into the furnace, so that the stoker had nothing to do with it except to open the door on firing, he endeavoured to do away with all such apparatus by using very highly superheated steam; and he was surprised at the very small amount of water that one need put in—in a highly superheated condition—to effect chemical combination at high temperatures. So instantaneous was the effect of the superheated steam apparatus,

(Mr. A. R. Sennett.)
that he had been able to signal—by the Morse dot-and-dash code—from a steamer to the land by cutting off the smoke at will by turning the steam on and off. He would mention an experiment which proved that in an interesting manner, and he only did so to show how firmly he was impressed with the value and importance of prosecuting the experiments further. If one powdered iron in hydrogen very carefully—taking care to admit no oxygen—and put that powdered iron into a glass tube containing oxygen which had been previously dried very thoroughly, the tube could be placed in a spirit-lamp and the glass made white hot, despite the fact that oxygen was all round the powdered iron; strange as it might appear, the tube might be shaken as much as one liked, and yet the oxygen would not combine with the powdered iron if it had been properly powdered in hydrogen. But if that tube were connected to a bulb, and one drop of water were put into it, matters being so arranged that by breaking the bulb the water vapour should pass into the tube of oxygen and iron, the whole thing would go off with a flash. Knowing the value of the presence of an infinitesimal proportion of aqueous vapour under those conditions, he naturally thought that all that was necessary was to introduce water into the cylinder of a gas-engine to get a wonderfully good result. He thought the simplest way to make a rough experiment was to put a kettle of boiling water outside the inlet valve. He tried that experiment in France at Messrs. Peugeot's works, who at that time used two inlet tubes, and he put a kettle of boiling water opposite each. The result obtained showed material falling off in the records of the dynamometer. This—though *primâ facie* a negative result—did not in the least alter his opinion. Firstly, the vapour had to pass through the carburettor, and was likely to effect the gasification of the air; and secondly, as Mr. Rainey had clearly shown (page 794), aqueous vapour in the combustion engine was beneficial up to a certain point, but in excess, it reduced the output of the motor.

Concerning the author's suggested motor, he thought that such a type of motor would have its utility heavily discounted by the fact that the design made a very long engine; that a piston-rod and

stuffing-box had to be employed, and that the latter would probably give much trouble, because piston-rods in internal-combustion engines became very hot; in addition to which a crosshead and guide would have to be used, and unless these were entirely enclosed, much wear and tear would take place from dust. John Penn, he believed, invented the trunk form of piston now used almost universally upon internal-combustion engines, and this he did for the sole purpose of economising space and getting a shorter engine, and this, as all designers of automobiles knew so well, was a great desideratum in a motor vehicle.

Speaking of the engine design, the author had advocated, in regard to petrol motors for road carriages, that the shaft-line should be placed eccentrically in regard to the cylinder axis. What he had stated about diminishing the angularity on the working stroke and increasing it upon the idle stroke, was sound reasoning when applied to a single-acting steam-engine; but in regard to the internal-combustion engine, he (Mr. Sennett) felt, although the author had rightly said (page 719) that "all Otto cycle-motors are single-acting, high-speed engines of accentuated type, in as far as the initial pressure is greater, more violently applied and more rapidly repeated," yet the action of the two was not so analogous as the author had assumed, for one certainly could not look upon the compression stroke as an idle stroke; indeed it might easily be doing about 50 per cent. of the working stroke, and the strain due to this was not, as the author stated, such as to "constantly press the crosshead"—carriage-motors have no crosshead—"against one guide." As a matter of fact, in the compression stroke the piston was forced against the opposite side of the cylinder; therefore it was clear that if the angular movement provided for the latter be made 50 per cent. less advantageous than that for the working stroke, no good would result from this ex-axial disposition at all.

The author's reasoning also, in regard to the re-action due to inertia of the fly-wheel being one of the chief causes of vibration, should be qualified by the statement that this only applied when the car was standing, which however was the more important time.

(Mr. A. R. Sennett.)

He was heartily at one with the author when he said that the thing to work for is an impulse-every-revolution motor, and also with his advocacy of horizontal cylinders. He felt strongly that mechanically propelled road carriages would in the near future be driven by horizontal cylinder motors; indeed, that they would pass through a similar phase of evolution as had the railway locomotive. Headley's "Puffing Billy" and other first constructed engines had vertical cylinders, and oscillated terribly. Then came the "Rocket" with diagonal cylinders, marking a vast improvement in lessened vibration, and from that time forward the cylinders have been decreased in angle until they were now practically horizontal. The author's deductions, however, from a slight rise in the proportion of American cars using horizontal cylinders were quite misleading as to the trend of design, the total number quoted by him being less than a couple of dozen. Now if he had instanced the great change which had taken place in France within the last couple of years, he would have seen that, whereas, in 1898 for example, a considerable proportion of the manufacturers were using horizontal cylinders, they had now practically all gone over to the vertical type. Two of the very early constructors might be instanced: Peugeot Frères had for six years confined themselves to horizontal cylinders, but last year made the change referred to, and Delahaye—building since 1894—had just recently changed his design. If one asked a continental engineer a reason for this change he had referred to, he generally gave three: difficulty of lubrication; trouble with sparking and—his strongest point—the wearing away of the cylinders and piston on their bottom sides. In regard to this, he would like to touch upon a great advantage incidental to the employment of forward compression, such as the author foreshadowed in his own motor, and as he had recently seen carried out experimentally, namely, that it was in a high degree conducive to "sweetness" of running of the motor. A short time ago he had tested a motor in which a very large amount of play existed in the trunnion-pin at the smaller end of the connecting-rod; the motor was running at from 1,200 to 1,500 revolutions per minute; this, in the ordinary way, would have

occasioned distracting knocking; in this motor, however—which compressed into its crank-chamber—there was no knocking at all. With regard to the other objections—difficult lubrication and trouble in sparking; in his opinion it was easier to lubricate a horizontal than a vertical cylinder, and the sparking trouble could be at once got over by a properly designed plug.

It was not clear to him, in regard to the author's proposed automatically adjusting contact-breaker, Fig. 11 (page 707) if the diagram in the Paper was correctly drawn, because it would seem, when the brush rubbed upon the commutator plate at its broader end, ignition must necessarily take place at an early period. The forward edge of the commutator plate—it would seem—ought to have been parallel with the axis of the shaft, and only the tail edge inclined. Mr. Turrell in 1889 had varied the period of sparking in a somewhat similar manner. Turrell used a commutator plate arranged spirally upon the commutator drum, and by shifting the brush, as the author proposed, the period was of course varied. In motor vehicle construction complication was the thing to be avoided, as every automobile engineer knew by bitter experience. Every unnecessary wheel and stud, every bolt and nut should be exorcised, as if it contained an evil spirit—one as likely to exert its evil influence when one was going at top speed as at any other time—and therefore he thought it possible the extra complication due to the attachment of an automatic spark-controller might more than outweigh its advantages; and the same, he was afraid, might apply to the "increased expansion" gear the author proposed, this at the same time sadly cut into the strength of the crank. He regretted, with the author, the inertia shown by constructors in regard to studying the problems involved, and in making theoretical principles work in with practical exigencies.

The subject of self-propelling vehicles for common roads was a far too extensive one to be dealt with in a single Paper, and he thought good would result from the reading of another at an early date.

Discussion on 21st November 1902.

Mr. Ralph Lucas said that Captain Longridge had put forward in his Paper the statement that he thought the two-cycle engine must be the engine of the future for motor-car purposes, and Mr. Lucas therefore thought it would be interesting to those present to hear his experiences on the subject of a two-cycle engine. He had been manufacturing cars for the last three years fitted with that type of engine. In the Spring of the present year he exhibited at the

Fig. 35.

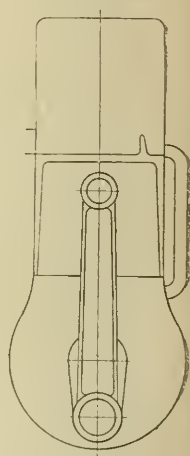
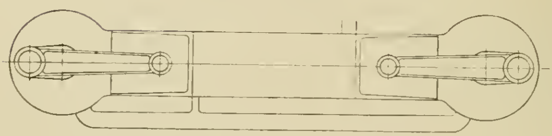


Fig. 34.
Two-cycle Engine.



Agricultural Hall a car fitted with a two-cycle engine similar to the sketch shown on Fig. 34. The action of the engine was as follows:—there were two cranks, one at each end, each coupled to a piston, and the two crank-shafts were kept in beat by a counter-shaft parallel with the axis of the cylinder, coupling them with bevel wheels. The two pistons must first be imagined to be coming together, thus drawing a charge into the crank-cases; then, as the pistons came outwards, they compressed that charge slightly. At the end of the outward stroke one piston uncovered a port in the cylinder, connected

to the crank-cases, and the other piston uncovered another slot to the atmosphere. The charge which was compressed in the crank-cases entered one end of the combustion-chamber through the first-mentioned port, and swept before it the products of combustion of the previous explosion out of the exhaust port at the other end; this charge was then compressed and exploded between the pistons, hence there was an explosion at every revolution with compression, and without valves.

Two or three of these cars were running on the road, and were running very successfully, showing that the two-cycle engine was already beginning to do something. Since then he had been encouraged, by the great power for weight he obtained from that particular type of car, to go a step further, and to design a car without change-speed gear at all, simply driving direct from the crank-shaft to the back axle with a single chain. On thinking it over, he found that a great deal of the weight of the former engine was due to having to use such a great weight of fly-wheel. As fly-wheels had to do the whole of the compression in all single-explosion engines, also there was considerable weight in the mechanism necessary to keep the two crank-shafts in beat; he therefore designed an engine of two single cylinders, with the pistons at opposite phases, so that each explosion did the compression of the other cylinder. It would be understood that the two-cycle engine exploded at every revolution, and therefore, with a two-cylinder engine, each explosion compressed the charge in the other cylinder direct without the storage of necessary energy in the fly-wheel, and thus the necessary fly-wheel weight became very small indeed; also no coupling mechanism was necessary to keep the pistons in beat, as they were both attached to the same crank-shaft, besides gaining the advantage of the continual torque, and therefore the little strain on the mechanism. A sketch of one of the cylinders was shown in Fig. 35 (page 800). The piston in ascending drew the charge into the crank-case, and in descending slightly compressed it, then uncovering a port connected to the crank-case and another to the atmosphere; this very slightly compressed gas rushed into the cylinder, and swept out whatever was there through the other port; the piston then ascended

(Mr. Ralph Lucas.)
again and compressed it and it was exploded, so that at every revolution above the piston there was an alternate compression and explosion, and at every revolution below the piston the charge was being got ready for the next explosion.

There was another point about the two-cycle engine on which he did not think the author had laid sufficient stress, namely, the continual thrust on the connecting-rod. It was well known that, in the Otto cycle engine, it drew in the charge at one moment and compressed it at another, and a change of thrust occurred therefore on the connecting-rods. That was prohibitive to very high speeds, and it was found in practice that 600 revolutions per minute also was the maximum speed at which an Otto cycle engine could be run, without fear of damaging the connecting-rods. But the two-cycle engine compressed at every revolution, and therefore the connecting-rod was always in compression. In illustration of the value of which he mentioned that, about three and a half years ago, he installed a two-cycle engine in the country for pumping water, putting it in charge of an inexperienced man—so inexperienced that when he was given the charge of an incubator he put the thermometer in with the bulb outwards, and could not understand why he cooked all the eggs. That engine had been running for twenty minutes a day for three and a half years, and had never required any repair at all, although the attendant did not know what was inside the cylinder. He (Mr. Lucas), in looking at the machine recently, took off the cylinder cover, took hold of the deflector plate on the top of the piston, and found there was something like $\frac{1}{8}$-inch back-lash in the connecting-rod, but the engine ran without knocking, because the piston was cushioned at every revolution. The two important points on which to lay stress were, first of all, the continual thrust on the connecting-rod, enabling the engine to run continuously at a higher speed than was usually possible with the Otto cycle type of engine, without any fear of damage from knocking due to wear; and, secondly, the great power for weight which was obtained, so much so that he had been able to make a car which would run without change-speed gear at all, which, with a light load of two passengers, could be geared to a maximum speed of 40 miles an hour and still successively

negotiate hills; or, gearing to a maximum of 30 miles an hour, would carry four people and the extra seats, etc., for the accommodation. These figures were from a recent 1,000-mile test of the first of this type. He thought that he had shown that the two-cycle engine was beginning to make its way already.

Mr. M. Holroyd Smith hoped that, if in the course of his remarks he said anything which was not quite relevant to the Paper, he would be called to order. If Captain Longridge considered the criticisms he would make were somewhat severe, he trusted that gentleman would consider they were in the interests of Science, and that they were not prompted by any animus. The Paper under discussion was entitled "Oil Motor Cars of 1902." He had looked through it, but almost in vain, to find anything relevant to Motor Cars of 1902. If instead of that title one took a passage which occurred (page 742), and changed the title to "The present Technique of Motor-Car Manufacture," it would have been a very much more correct title, and would have made the contents of the Paper more admissible, and therefore itself more genuinely interesting. In his opinion it had to be dealt with and discussed on the basis of what it was said to be, and upon those lines he proposed dealing with it as briefly as possible.

The Paper commenced with the statement that the author did not "wish to burden members with details." He wished to draw attention to the fact that details were both advocated and illustrated on pages 683, 684, 687, 706, 722, 730, 731, etc. None of those details, as far as he knew, bore any reference to work done in 1902. In most of the cases the matters touched on were ancient history. Some of them were suggestions for new devices. With perhaps one exception, he did not believe there was anything in any of those illustrations which he had quoted, which Captain Longridge would seriously advise any motor-car makers to follow. He asked the members to look at one or two of them. At Fig. 4 (page 683) the author said a great deal about angles and corners and ins and outs of motor-cylinders as, in his opinion, badly designed by other people, and yet he gave at Fig. 4 what he proposed as a solution of a

(Mr. M. Holroyd Smith.)
difficulty. He ventured to say that Fig. 4 was an error. The idea was that the gases should have a more uninterrupted and uniform flow out through the exhaust valve.

Captain Longridge said that uniformity of discharge was the object in view.

Mr. Holroyd Smith said he was only taking the Paper as it stood, and not a fresh interpretation of it. The statement was that it was an advantage to prevent the scarring of the sides and seat of the exhaust-valves by a too great rush upon one side thereof, and it would be found, not only in treating that one item, but further on, that there was an elaboration of the desire to have the gases flowing in a continuous course. He wished to show the error of that solution which was given in the Paper, because the suggested "improvement" would make the matter worse. It was only necessary to exaggerate the point to see the mistake. Consider the cylindrical chamber a little deeper than that shown in Fig. 4 (page 683), the down-rushing gases would beat upon the mushroom head of the valve and be deflected, and there would be conflicting movements, hindering and not helping the outflow. He thought that, if Captain Longridge wanted to get a better outlet for his gases, he should advocate a simpler plan of arranging the valve-chamber. Instead of, as was unfortunately the practice in dozens of engines, having the sides close to the edge of the valve, by enlarging the diameter of chamber, as in Fig. 33 (page 786), all that was wanted would be obtained, without making another evil in trying to cure the one mentioned.

On page 683 another illustration was given, though he did not know why. It could not be for the information of the members, because it was old, and most of those who were well acquainted with petrol motors had seen it years ago. He referred to the double-valve arrangement. When one found it advocated in the Paper that the induction-valve should be much larger than the exhaust-valve, he failed to see the consistency of giving such an illustration as that in Fig. 5 (page 683) where, obviously the induction-valve was very much less in diameter than the exhaust-valve, the very reverse of

what engineers were advised to do in other parts of the Paper. He would like to know if an engine like that had ever been built, and if so, with what result. Having regard to the terminal pressure usual in petrol motors, he would also like to know what strains and what wear and tear there would be upon a cam that had to lift an exhaust-valve of such an absurdly large area as that shown on Fig. 5.

Proceeding a little further one came to Fig. 6 (page 684). In respect to that he thought there was a mis-statement, namely the addition of 50 per cent. to the outlet area obtained by a device of that kind. It might be there, but he failed to see it. What he did see, however, was the possibility of a considerable amount of trouble in keeping all those faces as drawn—he did not say as intended—but, as shown, there were practically three faces to be ground. There were the dual faces of the valve and the valve-spindle, which was also shown with a conical seating, making three resting places for the valve. It was well known that when there were two or three edges of different diameters, with a bumping action going on, they would not all wear uniformly, and he took it that the valve must be frequently re-ground. Was he to understand that engineers were seriously advised to use valves of that kind?

He now asked them to turn to page 706, where there was a drawing representing the feasibility of automatically timing the electric-ignition spark. He wished to ask if Captain Longridge seriously advised anybody to adopt the interesting but tricky arrangement shown on Fig. 10. Everyone knew that for motor-car work it was necessary to get things as simple as possible. Adding a detail like that must necessarily add to the complications and difficulties in working. Further than that, the very device there indicated showed an arrangement which he thought by this time was quite obsolete, namely, the employment of a disc of vulcanite or other insulating material, and just a little bit of inlaid metal for the spring point to make contact with. There would be constant friction throughout the whole revolution of the disc, when contact was only wanted for a short period, and in addition the arrangement gave ample opportunity for the accumulation of oil and making bad contact. He presumed that makers of petrol motors in 1902 were not advised to use a device of that kind.

(Mr. M. Holroyd Smith.)

On page 722 was presented a solution of the vibration question, which, unless his memory was altogether wrong, was a known device by engine builders when he was quite a boy. Therefore he assumed it hardly came under the term "Motor Cars of 1902." On page 730 there was another device which was interesting. There was shown an internally-applied brake, in regard to which, if search were made in the archives of that Institution, it would be found that there was a diagram some fifteen years old which was practically identical with that given in the Paper, and now called a new device. On the next page another brake was shown, which was said to come from France. He could understand it coming from France, for the simple reason that, in 1894, he (Mr. Smith) sent that particular design to a French engineer for application to tramcars. On page 734 was given, a method of attaching a motor to its supporting frame by rubber buffers. He thought those who had been practising motor-car designing would agree with him that that was not new. He himself used it three years ago in motor cars, and probably some of those present had applied the same device to motor cars before that date. Fifteen years ago he had used identically the same thing on tramcars. He again reminded members that the Paper purported to be on "Motor Cars of 1902"; yet one might take the majority of details given in the Paper, and deal with them in a similar way.

In Fig. 16, Plate 78, there was a little contrivance illustrated for opening the exhaust free without passing through the silencer. No doubt many of those present had, like himself, used contrivances for the same purpose, so the object of it was old. The arrangement there shown was a pretty and interesting detail, and it was the manner in which it was carried out that made the device useful, and justified its introduction in the Paper. The object of his remarks so far had been to combat the opening sentence of the Paper, that "the author does not wish to burden members with details," and yet the reader had been burdened with useless details. But, on the other hand, readers had not been given, with only, he believed, two exceptions, details which were new and details which were useful. He held, especially with motor-car work, as in the majority of engineering work, that it was the excellency of the contrivances as to

little devices and details which made a thing a success or a failure, and instead of having long descriptions and a great many abstract generalizations, engineers would be very much richer in their everyday work if fewer pages of letterpress were presented to them and more useful details.

The next point in the Paper upon which he wished to touch was the technical teaching. If the details given were not of much use, what about the technical teaching? He had been approached two or three times, since the Paper was read and published, with the remark that Captain Longridge was advocating retaining the exhaust charges in the cylinder. He found that the words were capable of conveying that meaning. He thought that the author was advocating, not the retaining of the exhaust charges in the cylinder, but rather than have a low compression by throttling the intake and losing the high compression, it would be better to retain some of the exhaust charges, in order that, when the engine was governed by throttling the intake, one might still have a high compression. That, he understood, was what Captain Longridge meant, but it was so indefinitely expressed that it led to an error which was growing, and an error which had been repeated to him four or five times by different people. It was a pity that the author did not show how the engine could be governed by so-called "throttling," without lessening the compression, and without retaining the exhaust.

Another point was that the author rightly advocated high compression, but he did not give the least idea of what that compression should be. Was it to be something between 50 and 100 lbs., or what? What was the best initial compression to have in an engine? It would be an advantage to have some precise and useful information on that point, not merely a general statement. There was surely some limit beyond which it would not be wise to go. What was that limit, and how was it to be obtained? He would also like to have some information as to the best area for the valves in high-speed engines. A great deal was said about that in the Paper, but there was absolutely no reliable information given. There was a formula (page 685) which was credited to Mr. Roots, and he was very glad to find that Mr. Roots had been mentioned,

3 I 2

(Mr. Holroyd Smith.)
because few men had given more patient and persevering study to the question than he. Perhaps Mr. Roots, in persisting in the employment of "heavy oils," had worked on wrong lines, but he had persevered in his work, and all credit to him for doing so. He wished to ask if the author seriously put the formula before the members for their use, because, given an engine of $4\frac{1}{2}$ inches diameter with a 5-inch stroke and 1,000 revolutions per minute, one would require the exhaust-valve to be 3 inches in diameter. Would anyone seriously advocate a 3-inch diameter exhaust-valve for a cylinder $4\frac{1}{2}$ inches in diameter? He thought not.

At another part it was found that Captain Longridge had advocated the introduction of water in slight doses into the cylinder, but he did not point out the very great danger and difficulty that arose from adopting such a course. Water would get into the cylinder when it was not wanted. Most engineers had probably found that if there was just a slight leakage from the cooling chamber it gave a better running for a time to the engine, but there was very great danger from that, because, if the water could leak in during the suction-stroke, then, when the explosion took place, the hot gases would be forced back into the water-jacket, boiling up the water at a furious rate; there were other dangers in the use of water which readers of the Paper had not been told of. Nor had they been told how to apply fresh water well and wisely for useful purposes in the cylinder. That was a point upon which he would have liked to have some information.

On page 687 there was given just the germ of a detail which, if time had permitted, he would have liked to have spoken upon and elaborated, because, if fully worked out, it would be a good point gained, and he would have liked to have given the meeting the benefit of his own experience in the same direction. There was one point in the Paper which he thought most of those present would sincerely thank the author for, and that was what he had communicated on the question of the composition of the iron to be used in cylinders, etc. Members would also thank the author for his dissertations upon the component parts of gases. Those were matters of great interest and very useful, and he was indebted to

the author for them. Still, they were more questions for the metallurgist and for the chemist, and they scarcely came within the scope of the title "Motor Cars of 1902." The fact was that in the Paper a great deal too much had been attempted, and often when that was so, the result was largely spoiled.

He would next like to deal for a moment with the prophecies in the Paper. After the sentence which he had quoted as to burdening members with details, there came three prophetic pages. Those dealt with some motor which was going to be made. But there were no drawings given, and no detail supplied. The words used to describe the coming motor were almost identical with the description given of a motor which was submitted to him (Mr. Smith) four years ago, the invention of a French lady, but from this nothing had yet been produced. When the author had completed his experiments, it would be interesting to know the result. Thanks were due to him for the research and the patience which he had shown in producing so long a Paper, and to the numerous people who had supplied him with data; but he could not help expressing regret that more actually useful detail had not been given for the guidance of engineers.

Mr. J. Hartley Wicksteed, Vice-President, said Mr. Holroyd Smith had stated that in his memory the sketch Fig. 19 (page 722) was the same as the Roots blower. It certainly was not the same. It might have parts which were similar, but they were by no means identical with the Roots blower. The ordinary Roots blower was made with one piston. It had a very wide crosshead, and two very wide-apart connecting-rods. It was one piston driving two frames, whereas in the sketch, Fig. 19, there were evidently two pistons driving.

Mr. Holroyd Smith said he had seen some with two.

Mr. Wicksteed replied that all he himself had seen were made with one.

Mr. John Johnston said that, although he had sent in a written communication (page 857), he would like to add one or two remarks.

(Mr. John Johnston.)

As a worker in the field of the impulse-every-revolution engine, he had done something, he thought, to prove that that engine was equally as good and equally as economical as any Otto cycle engine in existence. He realised that that was a point upon which people did not agree. Most persons to whom he had spoken on the point held up to him that an impulse-every-revolution engine was not economical. In the communication which he had sent in, he had got a horse-power out of a 4-inch cylinder with a 6-inch stroke on $\frac{7}{8}$ pint of ordinary American petroleum. He did not think there was anyone in that meeting who had obtained a better result out of an Otto cycle engine of that size. As for the power, with a 4-inch engine running at 600 revolutions he worked it to $7\frac{1}{2}$ brake-horse-power, and he did not think that power could be got out of any Otto cycle engine running at the same speed. In regard to speed, he thought it was Mr. J. H. Knight, of Farnham, who had said it was an impossibility to work an impulse-every-revolution engine at more than 300 revolutions, without the engine bringing up through back-firing. He had worked his engines up to 800 revolutions and over, and he thought that was fast enough for any motor. He did not go in for very high speeds, but he had worked it up to over that speed with the greatest ease, and with perfect balancing. It was a simple balancing by the fly-wheel; there was no double piston required. That which a previous speaker had mentioned, namely, constant thrust on the connecting-rod, was a great point in favour of it, because there was no drag on the piston in the backward stroke. It was advantageous on all the points which were brought forward—economy, weight, and ignition. Mr. Beaumont said (page 765), in fact, that it was just as easy to multiply the number of cylinders on an Otto cycle engine as to make an impulse-every-revolution engine, getting two impulses to the Otto cycle's one. But on the point of ignition alone the impulse-every-revolution engine scored, because it was the most difficult matter to handle in connection with motor cars. Ignition gave more trouble than all the remaining parts of the motor put together, at least that was his experience, and it probably was the experience of many more.

Mr. Mervyn O'Gorman said that their thanks were due to the author for a suggestive Paper calculated to draw a discussion. Such a Paper did not deserve to be criticised as if it claimed to give original experimental results. Its title indicated that it would record the features of motor cars which were used in 1902, and whether the details were old or new he thought that the majority of them were in use on various motor cars used and built in 1902.

With regard to the proposed engine, he thought that all motorists of experience would agree that engines as now built were the feature on most cars that gave least trouble. The ignition, the gear, the springs, and the circulation were the causes of anxiety. Therefore a very good case must be made out for any new engine that was launched. The "raison d'être" of a new engine must be that it afforded improvement in one or all of the following points:—

(*a*) Plant efficiency.

(*b*) Running efficiency.

(*c*) Simplicity.

(*d*) Elasticity.

(What he meant by elasticity would appear from the mental comparison of the explosion engine with the steam-engine.) How were these qualities improved in the suggested engine?

(*a*) Was it cheaper per horse-power? He thought not. Was it lighter? Possibly, since it had two explosions (and Mr. Lucas made a strong claim for his engine on this very head) in lieu of one, but also, possibly not.

(*b*) Did it burn less fuel? and cost less for repairs? Neither of these were at all proved. [The author omitted to put in his claim for constant thrust, which would come under this heading.]

(*c*) It was not simpler.

(*d*) It was somewhat more elastic.

Adding these effects together, the author did not make a strong showing until he brought experimental evidence. Mr. Lucas's car was installed without gear, and he would have admired the result, were he not in possession of a car which dispensed with gear in all its normal running, which had been run for two months over 3,000 miles and which worked on the Otto cycle. This was done by using

(Mr. Mervyn O'Gorman.)

a fly-wheel, whose inertia was large compared to the weight of the car. The car was about 8 cwts. and the fly-wheel about $1\frac{1}{2}$ cwts., acting at a very considerable radius. (The fly-wheel diameter was about 24 inches.) The gear was only used on abnormal hills. He did not name the machine, as it was not his business to advertise the car, but he believed the absence of three gears would be the characteristic of next year's cars.

He had a device which would give to an Otto cycle car a measure of elasticity (that is, increased torque at slow speeds) by sacrificing at slow speeds a little more fuel per horse-power. It was about to be made, and he thought he might mention it appropriately now. It consisted merely of supplying the mixture to the motor under a small pressure, a pressure slightly in excess of that of the exhaust gases at the end of the exhaust stroke. With this, one opened the inlet valve a short time before the exhaust valves had closed, and the incoming fuel blew the residual exhaust gas out of the combustion chamber or clearance spaces of the engine. Now on Otto cycle engines, working at a compression pressure of 60 to 70 lbs., the clearance volume was about 1-5th to 1-6th of the cylinder volume, and as this clearance remained normally full of waste products, whereas with his pressure feed he replaced these with fresh stuff, he obtained an increased output from any engine of 1-7th or more, say a 15-per cent. improvement. This was his claim under (*a*), or Plant Efficiency—more output from a given engine. He found, as Mr. Lucas did, that one might easily obtain from the crank-chamber a supply of air under a small pressure, about 3 or 4 lbs. per square inch. To do this, it was only necessary to put on the crank-chamber a couple of mushroom-valves, one to let air in and one to let it out, and he put this pressure-air supply through the ordinary carburettor.

To obtain an improvement under (*b*), or Running Efficiency, it was only necessary to heat the ducts containing the pressure air. It was not necessary to point out why the hotter fuel would give more power; but it was to be noted that with the simple suction usually adopted, it was not possible to heat the air, owing to its expansion causing a diminution of the amount taken in per stroke, and therefore a diminution of the engine output. With a pressure

supply this defect vanished. With a pressure supply, it was to be observed that a mechanically-actuated valve was necessary, so that the spring on the inlet might be strong enough only to open when it was told to do so by the cam. By using hot gas, he hoped to make good his claim for fuel efficiency.

As for Simplicity, it was true that the valves were an addition to the parts, but they certainly were a very small encumbrance, and their exact action at a specific instant was of no consequence, unlike the automatic induction valve on the combustion head of the standard engines.

Under heading (*d*) Elasticity, this method had merits on starting and hill-climbing when, owing to the slowness of rotation, the horse-power was lowered, and the utmost torque was required; it was possible to improve the torque by allowing the crank-chamber pressure to rise to a fairly high value, say, 4 lbs. per square inch. This resulted not only in filling the combustion chamber with fresh gas in lieu of exhaust gas, but furthermore the entire cylinder charge was pressed home, not by atmospheric pressure of 14 lbs. per square inch, but by a total pressure of 18 lbs. per square inch, a 33 per cent. increase of pressure. Hence a 33 per cent. increase of fuel taken, and, say, 30 per cent. increase of torque resulted. (He did not need to point out that there were two pumping strokes on the front of the piston to each explosion, so that there was plenty of air available.) He advocated external fly-wheels of large inertia and small weight, and with an increase of torque at command, such as he mentioned, he could dispense with gear save for emergencies. Reverting to the details of valves as dealt with by the author, he strongly endorsed his view of the advantage of the mechanically actuated inlet, after trying both systems. The author advocated large valve-area, and he himself agreed; but there were limits to this, owing to the increased inertia and the difficulty of seating with large valves. A simple device to get a large opening without large valves might be mentioned briefly, in connection with a Paper which dealt entirely with devices and details.

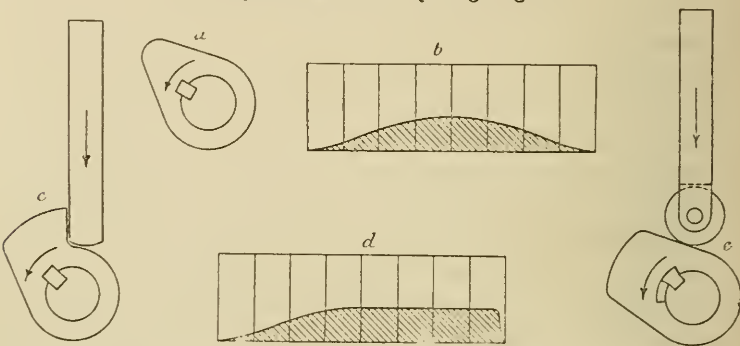
The ordinary valve cam, sketch (*a*), Fig. 36 (page 814), gave a diagram of opening, as sketch (*b*), where the height of any ordinate

(Mr. Mervyn O'Gorman.)
showed the amount the mushroom was raised, and the abscissæ the various positions along the stroke. The theoretically desirable cam (*c*), which would keep the exhaust port fully open to the end of the stroke as in (*d*), and give 50 more total valve-lift, was impracticable, because the unavoidable reversals of the engine down hill or from back-firing would break off the stem of the valve-lifter. To get the result without the drawback was easy. If the cam be mounted in such a manner that it became loose on the shaft (*e*), at the moment the exhaust stroke was due to be complete, the identical diagram (*d*) was obtained, and rotation in either direction was equally easy. On

Fig. 36.

Cams for operating Exhaust Valves.

Ordinary Cam and Valve-opening diagram.



Quickly-closing Cams with Valve-opening diagram.

a particular standard engine of very popular pattern, his friend, Mr. Cozens-Hardy, and himself made this alteration to the cams of both exhaust and inlet valves, and the increase in power, though large, was nothing to the increase of speed available; simply because this otherwise well-made engine could never get rid of its exhaust or suck in a full charge at very high speeds, owing to valve throttle. Incidentally it would be found that by keeping the inlet-valve uniformly open throughout the stroke, a more uniform carburation was obtained. This arose from the fact that the richness of the charge unavoidably depended upon the rate at which the air

was sucked past the carburettor; and at the end of the stroke, when the piston was moving slowly, if the speed of the incoming air was further diminished by the constriction of the valve passage, one was liable to obtain too poor a charge in the vicinity of the inlet, which was invariably the situation of the igniter. Hence to get uniform firing, one was led to use a charge the average of which was too rich, and the result of which was inefficiency and smell.

He wished to put in the most urgent and emphatic plea for the standardization of bolts and nut-heads, if not universally, at least on any one machine. If standard threads were impossible, let standard nut-heads at least be kept to, and let every bolt of every kind have a screw-driver notch in its head to facilitate the initial stages of screwing it in, leaving the spanner to finish the tightening.

With regard to ignition devices, there could be no question that the author was right in accentuating the importance of accurate timing, and, if it could be simply and reliably done, of automatic timing. To get the best output from the engine, one might ignite at the best moment, at any other moment evil results followed, namely (*a*) either the crank-pressure was excessive, without any adequate return of useful work; this occurred with early firing: or (*b*) the maximum pressure occurred too late, and the combustion was not complete when the exhaust opened (with smell and waste of fuel); this occurred with late firing. The finding of the happy mean was left to the activity and skill of the driver in almost all motor cars, and he could only use the method of trial and error. When obliged by a hill climb to change his gear ratio, the driver (who had many levers to manage) was very often compelled to use his engine inefficiently, firing the best of his pressure into the exhaust, and getting a diminished torque at the very moment when he wanted all his output. This arose from the increased speed of the engine, attendant upon the use of the lower gear. The greater speed called for an earlier ignition, but the driver was too busy to give it until a few seconds later. He then hunted for the "best moment." If he was skilful, he obtained it soon, if not the further slowing of the engine might compel him to drop to a still lower gear to avoid a stoppage by overload. This sequence of events was the more

(Mr. Mervyn O'Gorman.)

objectionable, if the engine was really adequate for the work when doing its best duty at all times. The use of automatic timing was therefore that it enabled a smaller engine to yield a better average speed and efficiency; it secured the driver against waste of fuel and against heavy crank-pin stresses from premature explosions. The possibility of an automatic device turned upon the fact, not pointed out by the author, that in any engine having a combustion chamber of fixed volume fired from a fixed point (not in the centre of that volume), the maximum pressure occurred at practically a fixed time after the ignition.

He did not think that, if the author had been as deeply concerned in the motor bicycle as he was in the larger automobile, he would so readily dismiss the floating straws of help, which were held out in the shape of catalytic ignition, to the designer of the motor bicycle. To carry accumulators, coils, and sparking plugs, and electric timing gear weighing together about one-eighth of the weight of the entire vehicle, and occupying one-quarter of its entire volume, was a serious matter, and if this weight could be reduced to three ounces and the volume to that of the sparking plug, there would be an extraordinary enthusiasm among cyclists which would help them to tide over the initial difficulties and failures.

Captain Longridge later drew attention to a point which had rarely, if ever, been publicly dealt with before, namely the adjustment of the duration of electrical contact in proportion to the speed of the engine. Usually the primary circuit of the ignition coil was closed, only while an uninsulated rotating segment made contact with the brush. If the segment was wide enough to give sufficient duration of current for a good explosion at high engine-speeds, the duration of contact was needlessly great at low speeds, sometimes in the ratio of 4 to 1. In order therefore to fire properly at top speed anything up to four times, too many electrical units were wasted when travelling slowly. Hence the capacity and consequent weight of the accumulators was twice or thrice greater than need be on a rational system of contact-making, such as he outlined. Having clearly understood this point, one was surprised to find the author complaining that the mileage claimed for

accumulators by their manufacturers was never obtained. Clearly it depended on the speed at which those miles were covered. The accumulator-maker could possibly guarantee it, and he expressed his storage capacity on miles, solely because his lay purchasers simply could not understand ampère-hours.

When the author suggested that a slightly higher compression should be obtained in the engine than was intended to be used at the moment of firing, he touched difficult ground. It might be taken as proved, that the fuel efficiency of an "Otto" engine, when ignition was supposed to occur at constant volume, depended—paradoxical as it seemed—on the compression-pressure at the time of ignition, rather than on the maximum temperature attained on explosion. From this it followed that a well-designed engine was worked at the highest compression which could be obtained at slow speeds from the fly-wheel, and which could be relied upon not to produce pre-ignition, say, from 60 to 90 lbs. per square inch. Therefore a very good reason indeed must be given for sacrificing any part of this efficiency, after it had been earned by the negative work of compression. His reason appeared to be chiefly to avoid excessive crank-pin pressures, and experience tended to show that these did not exist with the ordinary motor-car engine, save on the occasion of a mistake by a driver. He himself had suggested the best way to avoid such mistakes by automatic timing.

Mr. J. D. Roots said the Paper was so rich in opportunities for criticism that, as his time was limited, it was only possible to deal with two or three of the numerous points inviting criticism. At the bottom of page 669 there were the words "Room for a longer stroke—a requirement for the use of alcohol and heavy oils." He did not know if that was a misprint; if it was not, it distinctly implied that a greater expansion was obtained with a longer stroke than with a shorter one in the Otto cycle. That was certainly an error, possibly a popular one, but one which he did not expect to meet with in this Paper.

Captain Longridge apparently was a believer in the benefit arising from retention of the exhaust. He had imagined that that

(Mr. J. D. Roots.)

was an idea which had long ago been exploded, and he was rather surprised to see it cropping up again. If one were going to retain a portion of the exhaust with the new charge, solely to reduce power for governing purposes, there might be some advantage, but he did not think that, perhaps with the exception of Mr. Grover, any experienced engineer would say that there was any benefit arising from the retention of the exhaust in any internal-combustion engine, from the points of view either of efficiency or of power. It was very much like that doctrine of stratification of which one heard so much years ago, but which he hoped was now buried.

There was a paragraph (page 675) commencing "While the majority of makers have been caught by the 'drawing office' solid-head water-jacketed design, a few more practical makers, such as 'Panhard,' 'Mors,' and 'Napier,' have followed the plan of casting the cylinders separate, and adding a light aluminium, or rolled metal, water-jacket." In 1893 when he (Mr. Roots) made, as he believed, the first vehicle motor (with the exception of Mr. Butler's) which was constructed in this country, one of which he exhibited in 1894 at the Stanley Show, the engine had that form of jacket, sheet metal pressed on to the cast cylinder. So there was nothing very novel about that. The reason why at that time he did not use the cylinder cast with the jacket was, because it was almost impossible to get them without blow-holes and flaws. Now that he was able to get them, he was among those who went in for what was called the "drawing-office solid-head cylinders," and he was only too glad to get them. One heard continuous complaints about rapid wear upon the spindles of the ordinary mild-steel valves, but he believed that that wear was almost entirely due to the insufficient area of the valves and ports. In those engines in which there was ample area of valves and ports, he did not think that occurred, at all events that was his experience. He thought also it would be the experience of makers of gas-engines. In the petroleum-spirit engines, the French makers commenced to manufacture with restricted port and valve area design, and they got burned-out spindles and pitted valve-seatings.

The author had quoted some formulæ of his, Mr. Roots' (page 685). He had reason to know that those formulæ were fairly widely used in this country, and he had understood also that they were used in one other country. After two years' further experience since the article was written in which the formulæ were published in "The Engineer," he did not think there was anything he would modify in them, with the possible exception that with a very rapidly-opening exhaust-valve—that is, with a sharp boss upon the cam, a little less than one-fifth of the stroke might be required at the stated number of revolutions, following the formula. Captain Longridge said the formulæ were "incomplete," because they did not state the resulting velocities of the gas-flow. But he had apparently overlooked the fact that, with varying engine revolutions or piston speed, there would necessarily be varying velocities of the gas-flow. He next said they were defective, because apparently they assumed a discharge at equal pressure in all cases. That was precisely what they did not do. Had the author read the paragraph which appeared prior to the formulæ in that article, he would have found it stated that the velocity would differ in the same engine with different fuels, and, given the correct proportion of valves and ports which could be obtained from those formulæ, a designer could work out for himself the velocity of the gas-flow when designing a particular engine. It was clearly stated in a previous paragraph that the different fuels would give different pressures with those formulæ.

The automobile journals of the present day did not attempt to distinguish at all between the "carburettor" and the "vaporiser." The present Paper treated them in the same way—it did not discriminate. Before 1896, when automobiles were first used in this country, engines using coal gas, petroleum spirit, and petroleum oil had been in use in this country for some considerable time, and the carburettor was recognised at that time, and since, by internal-combustion engineers, as applying to apparatus for the mixing of petroleum spirit and air, while the word vaporiser was, and is, in general use as applying to the apparatus for heating and mixing petroleum oil and air in an internal-combustion engine.

(Mr. J. D. Roots.)

The author referred (page 737) to an experiment for mixing in a small tin vessel six drops of petroleum spirit with air, and proceeded to make comparisons between what might take place in an engine and what took place under those conditions. It appeared to him (Mr. Roots) that there was no comparison whatever. In the engine the explosive mixture was under compression, while in the tin vessel there was no compression. In the engine one had the mixture of spirit and air in approximately the correct proportions; in the tin, two, or four, or six drops of spirit were put in haphazard. Indeed, all the conditions and circumstances of this so-called scientific experiment with the tin were as different as they could possibly be from those which would take place in the engine, a comparison from which the author had made a deduction which could not be maintained, and was clearly without foundation. He ventured to think that this was one of those scientific experiments which were not to be encouraged, and he was not surprised that the author was not quite "satisfied" with the result.

The author had also said (page 737) that Messrs. De Dion and Bouton had patented a "self-igniter consisting of a small cylinder in communication with the main cylinder," in which a piston compressed a little of the mixture, and the ignition striking back fired the charge. It might be interesting to note that he himself had invented an ignition arrangement of a similar kind in 1896.

Mr. H. G. Burford said he thought the members owed Captain Longridge a debt of gratitude for bringing this very important subject before them. He agreed with one of the previous speakers, that the matter of the engine was not of such great importance as one would imagine from the remarks and criticisms which had been passed on the Paper. He also agreed that the majority of complaints and troubles which occurred were connected with transmission, ignition, and cooling; these were met with in constant work. However, the Paper would no doubt interest mechanical engineers in the country, and it would be interesting both to users

and engineers in England, if the subject of motor cars and their manufacture were taken more seriously to heart, instead of the industry practically drifting into the hands of people who were inexperienced in regard to mechanical effort or manufacture. From the Paper and from speeches one heard, it was declared necessary in many cases to go abroad for springs, axles, and other parts of cars, which it was said could not be obtained in this country. He was an Englishman to the backbone, and he believed firmly that if the English makers were given the chance, and approached in the right fashion, they would not be behind the French and German people in manufacturing those requirements.

An important point in the matter had not been touched upon, namely, that in the Gordon-Bennett contest a British-made car, one which was solely made in England in regard to springs, frame, engines, body, wheels, and every component part, won, and placed Englishmen in the possession of the cup. Automobilists, especially British, were proud to think that they possessed a car which held the premier position in the world. He thought English manufacturers should be given the same facilities or chances which the French or German nations possessed, and then there would be no doubt that they would hold their own and beat foreign competition.

He could speak for a long time regarding the valves and other matters which had been touched upon by other speakers, but he thought the engines of motor cars had been quite sufficiently dealt with. The automobile industry in this country had only touched upon the fringe yet. He had been associated for some two years with heavy forms of traction, and the inquiries which his firm received for that form of traction-engine were very numerous. He was a great believer in the internal-combustion engine as against the steam-engine for traction purposes. He had examples in which the internal-combustion engine had held its own against steam-engines, and the firm with which he was associated were building lorries for next year's work which would carry five tons, six tons, and even ten tons, and also machines for running on rails to take the place of electric tractors. He thought at the present moment there was scarcely an English firm which was turning its attention to heavy

(Mr. H. G. Burford.)

traction in petrol lorries, but there was a very great field for the English engineer in that direction, as well as for the manufacturer of the component parts if they would only turn their attention to these matters.

Mr. W. F. Maxwell Williams said the remarks he intended to make really had nothing to do with the subject-matter of the Paper, but referred to the title. The automobile in this country might be divided into three classes; firstly, the automobile used for business purposes, which he would compare with the cart-horse; secondly, the automobile used for pleasure purposes, which might be compared with the carriage-horse; and thirdly, that class against which the police were waging a war of extermination, which he would not compare with the racehorse, because that noble animal might object. There was a fourth class about which little was heard, namely, the automobile for military purposes. He thought there was no doubt that the field artillery of the future would be of a very different class to what it was at the present time; it would have a greater range, would throw a heavier projectile, the gun also would be much heavier, and the present gun-teams would certainly not be able to tackle such heavy guns. He supposed that, in the near future, the cart would be put before the horse, and the gun would go into action on its self-propelled gun-carriage, muzzle leading, or, as an American would say, "business end first," which, in these days of quick-firing, would appear to be the most sensible way.

He had risen for the purpose of suggesting that it might be worth while for motor-car makers to produce suitable design of motor-cars for military purposes, such as gun-carriages or ammunition wagons. He knew perfectly well what the answer to that suggestion would be, and he was afraid there was a great deal of truth in it, which was that they would not get much encouragement from the War Office. He ventured, however, to predict, with all respect to the War Office, and combining a little Scottish caution with a little Irish logic, that the War Office of the present would, in the future, be a thing of the past. There was no doubt, as one speaker had just said, that details were very important and special details would be

required in the motor for military purposes. For instance, a gun-motor would have to be a first-rate hill-climber. If an officer of the Royal Horse Artillery was asked what the greatest angle was up which his team of horses would drag a gun he would probably point to a wall for an answer, and he (the speaker) verily believed that if that wall had a little "batter," and there was an enemy on the other side, the officer and his team would get their gun to the top. A motor was required, therefore, which would take a gun up a very steep hill, and the gun-motor of the future would have to rival the goat in its scrambling powers, just as in the past the motor car had surpassed that animal in the loudness of its bleat and the vileness of its smell.

Among other necessary and important characteristics was speed, and he was sure no policeman would be found to swear that the gun was going more than five miles an hour if it scorched into action to get the first round away, or raced after a flying enemy to give him a parting shot. For the military motor no excuse need be urged for excessive speed; it would be a virtue, not a vice. There was another animal, the sea-shore crab, whose strong points might well be imitated in designing such a motor. Old Mother Nature had fitted that animal with an excellent reversing gear and a steering gear of which any tug skipper might well be jealous. It was a very necessary thing that a motor for military purposes should be able to stop suddenly, but that would be a serious matter, because a motor-gun carriage would naturally be very heavy; it would weigh not 15 cwts. but probably 4 or 5 tons or more. It would also have to be easily steered, that being of great importance in the manœuvring. The crab also exhibited another characteristic worth imitating, for when he had taken up a good position he got his little "digger" gear to work and quickly disappeared from view. If to the gun-motor carriage some such arrangement was attached for rapidly entrenching or throwing up a slight breastwork, it would be of considerable value. Very little had been said in the press about motor cars for military purposes, and he was sure no two members of the Institution could give a better opinion on what he had suggested than Captain Longridge, who was an old artillery officer, and the President, to

(Mr. W. F. Maxwell Williams.)

whom the country owed so much for valuable information on heavy ordnance in the columns of "Engineering."

The President announced that Mr. Crowden had forwarded a number of models and drawings which he wished to show to the members after the discussion (Plate 80, and page 842).

Captain Longridge, in reply, said it was very pleasant for him to rise, feeling that, as he had reason to open the discussion with words of thanks, so he now had further motive to close it with an expression of gratitude to the President and Council for kindly and generously extending the time allotted to the Paper, and to all the members who, by a numerous and continued attendance, had given tangible proof of the importance of the automobile industry, and, by their remarks, had shown the careful consideration devoted to its many problems. He recognised that much useful information could and would have been offered by other speakers had time permitted. He begged those gentlemen earnestly, very earnestly, not to deprive the Institution of their views and advice, but to convey them in written communications to the Secretary, so that when the discussion was printed it might form a varied and valuable contribution to the literature of the industry. His reply to the remarks which had been made must be brief because time pressed, and he had still to give the promised information on steel cylinders, and in connection therewith two metallurgical superstitions to confute.

Taking the remarks in the subject order of the Paper, the first referred to the title. From the insistence of three speakers on that point, he could but conclude that they desired not only a description of the cars, such as he had already explained was regularly and fully given by an admirable automobile press, but further a superadded critique. If those gentleman had reflected they would have recognised that, as a director of one company, it was impossible for him to publicly criticise the productions of that company; and in such case equally impossible, or at least very bad taste, to criticise those of its competitors. But apart from that, had he written a

Paper of this description, tantamount to an assembly-call to makers to come and cry their wares, he thought the Council might very properly have refused its acceptance as foreign to the scope of the Institution. But indirectly, analytically he had described and criticised all their cars; he had dissected them, and, laying the disjointed members before the meeting, had invited those present to say where each detail was at fault and how it could be improved, thus enabling them by mental synthesis to re-assemble the improved parts and build up a conception of the ideal car which was the one and common object they had in view.

Before further proceeding with his reply he thought it would be better for him to deal separately with Mr. Holroyd Smith's remarks, trusting this gentleman would take in a friendly spirit what he said. It was evident that Mr. Holroyd Smith had scarcely read the Paper. He had first animadverted on Fig. 4 (page 683) which he had entirely misunderstood. It was not a question of giving increased outlet for the gases, but a question of getting uniform outlet. By countersinking the valve, a uniform discharge all round was obtained which prevented the tilting action and the burning on one face. With regard to Fig. 5 (page 683), Mr. Holroyd Smith had evidently not read the foot-note. With regard to Fig. 6 (page 684), the triple valve, Mr. Holroyd Smith had again not read the Paper. The author had not asserted that there was 50 per cent. greater outlet; what he said was that the makers claimed to have it. With regard to Fig. 10 (page 706) he had not advised the members to adopt those particular devices; they were merely illustrations of what had been done in that direction. In every case his critic had said that the devices were ancient. Every one of the devices illustrated in the Paper was taken from cars of 1902. Most inventions were evolutions of old ideas. Let Mr. Holroyd Smith suggest something newer and something better. In his remarks on technical teaching, Mr. Holroyd Smith had accused the author of favouring retention of the exhaust. He wished to make his position clear on that subject. In his own particular engine he could only partially get rid of the exhaust. Therefore, naturally he was making the best of it. He drew in a full charge of air on the side of the piston where there was no

(Captain Longridge.)

exhaust, and he transferred the full volume to the combustion chamber, and there the residual gases served merely to increase the compression and heat the charge, thus improving its inflammability and combustion—two distinct advantages. In general, he thought the disadvantages of retaining exhaust gases in petrol motors were overrated. These gases added heat and were rarely inert. Mr. Holroyd Smith had asked what was high compression. He (Captain Longridge) thought that his Paper was addressed to engineers who understood what high compression in oil engines was. Mr. Holroyd Smith had also evidently not read the Paper with regard to Mr. Roots' valve formulæ, because, instead of advising the members to adopt these formulæ, he (Captain Longridge) had found certain faults which Mr. Roots had that evening taken the trouble to explain. Mr. Holroyd Smith complained that attention had not been drawn to the dangers of water in the charge. He (the author) did not know what dangers there were. If a hole was made in the cylinder and water was let in possibly there might be dangers. The speaker also thought that the composition of the cylinder metal had nothing to do with 1902 cars. He (Captain Longridge) thought that one of the most important points in the cars of today was the composition of the cylinder metal, because so many makers used water-jacketed cylinders which were exceedingly difficult to cast. Mr. Holroyd Smith also twitted him with prophesying about his engine without even giving the working drawings. They were not given, simply because they were not completed until the present week; in addition there were other reasons why they should not be given. No prophecy was made with regard to his own motor, the prophecy, if any, was his belief that the impulse-every-revolution type of motor was the one which would eventually be adopted.

He would now return to remarks made earlier in the discussion. With regard to the two-piston one-cylinder engine, Mr. Iden, Mr. Beaumont, and, he thought, Mr. Austin, considered that type objectionable, because it was complicated. It seemed to him that the word "complicated," as implying something that was intricate and liable to derangement, was not in place. That type of engine had fewer valves, and, although there were additional connecting-

rods, these were simple parts, and in light motors were not so objectionable as in heavier engines. It was certain that this class of engine, both in its vertical and horizontal form, had done excellent work, demonstrating the value of "balance" and impulse every revolution; the economic merits of rapid and extended expansion, with the mechanical advantage, as Mr. Lucas pointed out (page 802), of constant bearing thrust. It might interest the members to know that, in the recent New York 500-mile Reliability Trials, this type of engine had elicited in the American press special commendatory notices.*

With regard to horizontal and vertical motors, Mr. Iden, Mr. Beaumont, and Mr. Austin held that there was not much to choose between the two positions, although the last-named speaker claimed greater security in water circulation for the horizontal engine. There might be suggested, for the consideration of the members, another more important point of difference, namely, the facility the horizontal position gave for obtaining the same power with a longer stroke, slower speed, and therefore probably lower fuel consumption. This he would explain in his written reply (page 887). All three speakers held that the choice between the two positions was chiefly a question of transmission. That was a very important observation. If it implied any subordination of the motor to the transmission, the principle was, he thought, erroneous, because the motor must come before everything, and its evolution

* "A number of the most important American manufacturers have settled, after extensive experimentation, upon the opposed-cylinder slow-speed motor as the type embodying the greatest flexibility, reliability, and freedom from vibration, consistent with an avoidance of undue complexity and multiplication of parts, and it must naturally be a matter of regret to them to be forced by popular demand to discard this well developed type. There are two or three well known American manufacturers who are accomplishing splendid results with this form of motor, having a powerful balance-wheel. They were the very best hill-climbers in the 'bunch,' and made a far better showing in this regard than did the continental types of like rating."—*Horseless Age*, 29th October 1902, page 467. *See also* ditto, 15th October 1902, page 404 *et seq.*

(Captain Longridge.)

must be studied with a view of bringing the distance and the number of parts between the motive power and its work to the irreducible minimum. He considered Mr. Lucas was a manufacturer who had embarked on a distinctly progressive course in the elimination of change-speed gear. The members must all wish him success, because success meant to everyone a bridge over a nasty pit-fall. It appeared, from the French press, that one of the surprises of the forthcoming Paris Exhibition of Cars would be that of Messrs. Charron, Girardot and Voigt's car, from which all change-speed gear had been eliminated. With regard to the author's impulse-every-revolution engine, Mr. Beaumont and Mr. Sennett, the latter of whom referred to the Butler engine (page 794), thought the motor resembled a number of similar attempts. He was under the impression that both those gentlemen were confounding his motor with a fairly common type, in which, as in the Butler engine, the charge was received on the front end of the cylinder, transferred to a receiver, and then expanded into the explosion end. That was quite a different cycle, and one which he considered was open to several objections. Professor Burstall (page 771) attributed to the author's engine, perhaps inadvertently, the defect of rarefication or diminution of the incoming charge by cylinder temperature. That was a defect inherent in the Otto cycle, but absolutely eliminated in his engine, the air being received on the cool side of the piston in one cylinder, and then pumped without any possible loss of weight into the combustion chamber of the other cylinder. Therefore the temperature to which the air was raised while entering the combustion chamber was quite immaterial. Mr. Beaumont (page 764), while favouring increase of impulse, thought it was better obtained by a multiplication of cylinders. For many obvious reasons, partly enumerated in the Paper, he (the author) held a distinctly opposite opinion. He agreed with Mr. Sennett that double-acting motors, with explosion on each side of the piston, were not likely to prove satisfactory. Dealing with piston speed, Mr. Beaumont remarked it was not a question of piston speed, but of the number of revolutions. If Mr. Beaumont intended to infer that not only piston speed but also the factors of durability

and negative work, involved in an increased number of revolutions, were to be considered, he was quite right, and attention was expressly drawn to those facts in the Paper; but if he meant that piston speed was of minor importance to those factors, he was undoubtedly wrong. As Professor Robinson properly pointed out, piston speed was vital, because, on the one hand, there was a lower limit necessary for efficiency, and, on the other, an upper limit, beyond which the explosion and combustion were seriously affected.

In connection with cylinder material, he was afraid Professor Hiorns had undeservedly suffered for his (the author's) sins of omission. He ought to have stated that Professor Hiorns' suggestion of hematite was made on the assumption that the cylinder would be cast separate, and, a light jacket being added, the saving of weight would thus admit of greater wall-thickness, while the simpler casting would lessen the risk of blow-holes. There was no doubt that a ground cylinder of that material would present an excellent running surface. He apologised to Professor Hiorns for his want of explicitness, and agreed with him as to the excellence of the running surface of the material suggested. Some additional information on steel for cylinders had been promised, and, with the permission of the President, he would, on finishing his reply, return to that important and interesting question.

Both the automatic inlet-valve and the jet carburettor were advocated by Mr. Beaumont and Mr. Austin, because they were simple. If the speakers had said "looked simple" he would have been at one with them; but, when the internal troubles of defective volume and imperfect mixtures, due to erratic working of the valve and jet, were considered, as they must be, neither device was simple, but, on the contrary, fraught with complications. No doubt simplicity of look was the selling point with an ignorant customer; possibly both speakers were viewing the question from that standpoint. There was not sufficient time to refer at any length to mechanical valves, but he would like to read two of a number of communications, received from different makers on the point. Messrs. Milnes, who were using large engines of 20 H.P. and over, wrote saying: "We have used mechanically operated valves during

(Captain Longridge.)

the last twelve months on our 20-H.P. engine with excellent results. We claim that we get a more regular mixture and an increase of H.P., also a very much smoother and quieter running engine." M. Citroen, in writing with regard to the 1903 2-B.H.P. Minerva motor cycle, said, "I should be greatly obliged if you will communicate my views and experience on the use of mechanically operated valves. These are to the effect that the opening of the inlet valve independently of the suction ensures a full charge, and that valve sticking is eliminated, while an increase of 15 per cent. to 20 per cent. of power is observed." Subsequently, M. Citroen wrote as below.* In the one case, experience was given of the mechanically operated valve as applied to large motors, and in the other to very small motors. The ground was therefore well covered.

The extremely interesting remarks of Mr. Grover, Professor Burstall, Professor Robinson, and Mr. Sennett, on the residual gases

---

* "In the case of the bicycle motor, one of the greatest difficulties we have had to contend with, doubtless common to all manufacturers of small engines for this purpose, is of obtaining sufficient power for hill climbing, when running dead slow, without providing an engine unnecessarily powerful for ordinary use on flat or average roads. The difficulty we found was that with a spring on the admission valve, sufficiently strong for quick running, a very small charge of mixture is taken per stroke when running slow, consequently minimum power when maximum is wanted. This is caused by the late opening of the admission valve, as a slow engine of short stroke lifts a spring-controlled admission valve later and later in the stroke as the revolutions decrease, and *vice versâ.* Theoretically this should not be so, but when the treatment of these little engines by the majority of their users is considered, particularly as to want of care in lubrication, and occasional overheating, it is not to be wondered that wear of cylinder and rings rapidly reduces the force of the suction stroke and also of the compression.

"A careful consideration of these points, together with exhaustive tests of engines on the brake, artificially cooled by means of a fan so as to approximate working conditions, has amply justified our hypothesis, bearing in mind that for bicycle propulsion, regulation of the spring of the admission valve when running is inadvisable as adding complication, and a governed engine fitted with clutch and two-speed gear is a piece of apparatus that, in my opinion, would hardly be calculated to give satisfaction, unless in the hands of an engineer of experience who was also a skilled trick cyclist."

and water in the charge, would be dealt with later in the written reply (page 888).

With regard to ignition, he quite agreed with Professor Burstall (page 770) that a magneto, or even a dynamo with a starting battery, was much to be preferred to accumulators. It was rather noteworthy that nearly all large continental commercial engines had practically adopted a magneto low-tension system of ignition. It was regrettable that no speaker had gone more deeply into the questions of magneto ignition, and also of the point at which ignition was applied, because a great deal remained to be learned on both points. If Colonel Holden had been present, he would probably have mentioned some very curious things connected with the effect produced on the charge by firing at different points. On the proposition of the Paper that exhaust governing was more economical than volume throttling, Mr. Iden raised a by-question, namely, that the former system led to cylinder fouling by a retention of the exhaust gases. He (the author) had examined a number of cylinders of motors run on the "hit and miss" system with the exhaust retained in the cylinder, and had never observed undue fouling. In answer to some inquiries, addressed to firms using governing on the exhaust, the following replies had been received. The Motor Traction Co. wrote:—"The only experience we have had with motors governed on the exhaust has been with the German cars, and from our experiments with these we agree with you as to the economy of this method of governing over that of throttling on the inlet. As to the objection that you say is urged against governing on the exhaust, in all the German cars that we have sold we have had no complaint or any trouble arise from fouling of the cylinders and valves. We have just had a car at the works to overhaul which has been driven a large number of miles daily for the past five or six months, by a gentleman from South Africa who has been touring this country. This car is a four-cylinder 15-H.P. car, and the cylinders are quite as clean of the effects of fouling as in any car governed on the other system, of which we have, of course, had experience." The Manager of the Humber Co. wrote as follows:—"I do not think there is any doubt but that governing on the exhaust is more economical than governing

(Captain Longridge.)
on the throttle, but the latter is more advantageous than the former. One objection to governing on the exhaust is that, if the car is standing with the engine running for any length of time, the sparking plugs of the two cylinders which are cut out (I am speaking now of a four-cylinder engine) are liable to get fouled with the lubricating oil which works up through the piston rings. Governing on the throttle obviates this, as, when the engine is working, all four cylinders are in. Governing on the exhaust does foul the cylinders and valves." This fouling was not due to the retention of the gases, but to the working up of the lubricant, and he (the author) thought that it was only possible when excessive lubrication was used. There was another interesting letter from the Gillet-Forest Company, in Paris, who governed entirely on the exhaust. They wrote briefly as follows: "The special feature of our motor is a particular method of governing by the exhaust. The exhaust cam is so constructed as to allow of the exhaust-valve opening more or less, and also for a longer or shorter period. We thus secure a means of keeping in the cylinder a portion of the burnt gases that have just done work, which enables us to reduce appreciably the volume of fresh gas to be admitted. The first advantage, an economical one, is this: the exhaust-cam, actuated by the governor, only discharges as much of the burnt gases as is necessary, with the consequence that even a minimum fresh charge is sufficient to fill the cylinder." A second advantage touched the point which Mr. Holroyd Smith did not appear to have noticed, but to which he (the author) drew particular attention in saying that one of the reasons why he did not think the presence of a residual gas was so objectionable was because it served to maintain the full compression. 'The second advantage is that the compression remains constant, which is not the case with governing on the admission; the efficiency of the motor is thus always at its highest whatever the quantity of fresh gas admitted." "The third very important advantage is to be found in the perfect lubrication of the piston-rings. In consequence of governing by the exhaust, which only partly causes a vacuum behind the piston during the admission-stroke, the atmospheric depression being less, there is no tendency of the oil to work up

from the piston rings. With regard to the heating of the cylinder we have never had to take this trouble into consideration." *

With regard to lubrication, he thought Mr. Rainey's advice, to use, in the summer time, water in the crank-chamber, deserved very careful consideration. It had been tried in several cases in America, and the results had been very satisfactory. As a proof that

---

* *Letter to the author from the Société des Automobiles Gillet-Forest.*—" Notre type de moteur est en effet caractérisé par la régulation sur l'échappement très particulière que nous employons. La came d'échappement est faite de telle façon qu'elle permet l'ouverture plus ou moins grande et plus ou moins prolongée de la soupape d'échappement. Nous avons donc ainsi le moyen de conserver dans le cylindre une partie des gaz chauds qui viennent de travailler, ce qui nous permet de diminuer dans de notables proportions le volume des gaz frais à admettre.

" Un premier avantage, économique, est celui-ci : la came d'échappement commandée par le régulateur ne laisse échapper que ce qu'il faut de gaz brulés, ce qui permet naturellement de n'introduire que le minimum de charge fraîche pour compléter la cylindrée.

" Un second avantage est que la compression reste constante, ce qui n'a pas lieu dans le cas du réglage sur l'admission ; le rendement du moteur est ainsi toujours maximum, quelle que soit d'ailleurs la quantité de gaz frais introduite ; l'allumage se fait toujours avec la même facilité, et ceci en raison du phénomène bien connu et souvent constaté de la stratification des couches gazeuses, c'est-à-dire du non-mélange des gaz frais et des gaz chauds. Ces derniers suivent le piston dans sa course rétrograde, laissant la place libre pour les gaz frais aspirés, au fond du cylindre et autour de l'allumeur. Ces gaz frais sont eux-mêmes dans d'excellentes conditions d'inflammabilité, étant donné qu'ils prennent rapidement par contact une partie de la chaleur que contiennent les gaz brulés restés dans le cylindre.

" Un troisième avantage, également très grand, réside dans la perfection du graissage des segments de piston. En raison de la régulation par l'échappement, qui ne provoque qu'un vide partiel derrière le piston lors de la course d'aspiration, la dépression, étant minimum, ne tend pas à aspirer l'huile en trop grande quantité entre les segments de piston et les parois du cylindre ; il n'y a pas à redouter d'excès de graissage au cylindre, ni, par suite, d'encrassage de bougie ; nous n'avons jamais, quant à nous, reconnu un inconvénient de ce genre dans la construction journalière et le fonctionnement continuel de nos moteurs. (*For continuation, see foot of next page.*)

(Captain Longridge.)

premature ignition could not proceed from the inflammation of lubricant vapour, neither the experiments of Mr. Rainey nor those of Professor Robinson appeared conclusive. Mr. Rainey's excessive use of lubricant would result, if anything, in over-saturated vapour difficult to ignite; while Professor Robinson's test did not exclude

TABLE 4.—*Exhaust Valve Dimensions.*
(French practice.)

Diameter of Cylinder.		Diameter of Valve according to stroke.	
millimètres.	inches.	millimètres.	inches.
65 to 70	2·56 to 2·75	18—22—25	0·70—0·86—0·98
75 to 85	2·95 to 3·34	25—28—32	0·98—1·10—1·25
85 to 95	3·34 to 3·74	30—32—38	1·18—1·25—1·49

VALVE LIFT.

For cylinders 60 to 70 mm. (2·36 to 2·75 inches), lift is 5 to 6 mm. (0·196 to 0·236 inch).

For cylinders 70 to 90 mm. (2·75 to 3·54 inches), lift is 8 to 9 mm. (0·315 to 0·354 inch).

PORTS, PIPES.

Ports may be 5 mm. (0·196 inch) larger diameter than valve.

Pipes may be about 5 mm. (0·196 inch) larger diameter than port.

"En ce qui concerne le chauffage du cylindre, nous n'avons jamais eu à nous préoccuper de cet inconvénient, qui n'existe pas dans nos moteurs, en raison de notre système particulier de refroidissement par évaporation, qui nous donne absolument toute satisfaction, et qui ne comporte ni pompe, ni thermosiphon.

"En résumé et pour répondre nettement à vos questions:

"1. Il est indéniable que le système du réglage par l'échappement procure une économie notable, ainsi que l'ont prouvé nos voitures dans tous les concours officiels de consommation, oú elles se sont toujours placées au premier rang;

"2. Il est inexact que ce système provoque le chauffage et l'encrassement du cylindre. Tout au moins, cela ne peut pas arriver dans un moteur monocylindrique horizontal bien étudié et bien construit."

TABLE 5.—*Inlet Valve Dimensions* (French practice).

Diameter of Cylinder.		Stroke.		Diameter of Valve.		Diameter of Pipe.	
mm.	inches.	mm.	inches.	mm.	inches.	mm.	inches.
60	2·36	70	2·75	15	0·59	18 to 20	0·70 to 0·78
65	2·56	75	2·95	18	0·70	20 to 22	0·78 to 0·86
70	2·75	80	3·15	19 to 20	0·75 to 0·78	22	0·86
70	2·75	85	3·34	21 to 22	0·82 to 0·86	23	0·90
75	2·95	90	3·54	22 to 23	0·86 to 0·90	24	0·94
75	2·95	100	3·93	23	0·90	25	0·98
80	3·15	120	4·71	24	0·94	27	1·06
80	3·15	140	5·49	25	0·98	28	1·10
85	3·34	140	5·49	26	1·02	29	1·14
85	3·34	150	5·89	27	1·06	30	1·18
90	3·54	150	5·89	28	1·10	32	1·25
90	3·54	160	6·29	30	1·18	35	1·37

VALVE LIFT.

For cylinders 70 to 90 mm. (2·75 to 3·54 inches), lift is 5 to 6 mm. (0·19 to 0·24 inch).

INLET PIPE.

The diameter should be 2 to 3 mm. (0·07 to 0·12 inch) greater than valve diameter.

(Captain Longridge.)

the possibility of the lubricant vapour entering the vaporiser and there igniting. Several speakers had expressed views confirmatory of opinions offered in the Paper, and he was pleased to find that he was in accord with these members.

In response to a request for information on valve dimensions, he submitted Tables 4 and 5 (pages 834 and 835) given by the French author, G. Knap (Les Secrets de Fabrication de Moteurs à Essence), and he might mention that other Tables were given by Mr. T. H. Hawley (Motors in Principle and Practice).

He now wished, in the joint names of the members and for their joint interest, to thank the professorial body which had been so ably represented at the discussion. There was no one for whose opinions they had more respect than that of the professor; they appreciated his talents, his bent for research, his freedom from the bias which manufacturers developing one or other system were so liable to acquire, and they recognised also the great services which he had rendered to other trades where his aid had been sought. In tendering their thanks to the professors, he felt sure that all the members would join with him in asking their continued aid for the motor industry. He was pleased to communicate that Dr. Glazebrook, of the National Physical Laboratory, had written saying that he would try and give attention to the much-needed determination of the specific heat of petrol vapour, while Dr. Stanton had informed him that he was completing a testing machine for experiments on repeated and reversed stress, from which the members might hope to obtain much valuable information. Professor Turner, Professor Burstall, and Professor Robinson, by their attendance at the discussions had shown their practical interest in the difficulties of the motor-car industry, and he was certain he expressed the sentiment of the meeting when he gratefully thanked them for it. Finally he turned to the distinguished President and Council of the Institution, and with all the earnestness at his command, supported by the example of the professorial body, and appealing to the formidable array of living testimony of the importance of the industry, he again presented the petition with which his Paper concluded. If funds were required to extend the Gas-Engine

Research Committee to the Petrol Motor, he felt sure that if the points of research were such as appealed to the trade and impressed them with their practical importance, those funds would be forthcoming. Why? Because the solution of such problems would cost individual manufacturers far more time and expense, than if the investigation were carried out under the auspices of this Institution.

Going back to the subject of steel for cylinders, the firms to which inquiry on that subject was addressed were the Weldless Steel Tube Company, of Birmingham, Messrs. Krupp, of Essen, and Mr. Ehrhardt, of Düsseldorf. In the first instance those firms were asked to supply an analysis of the steel they recommended and were in a position to supply, and the results were shown in Tables 6 and 7 (page 838). With regard to the analysis of the Weldless Steel

TABLE 6.

	Weldless Steel Tube Co.	Krupp and Co.
	per cent.	per cent.
Carbon (by combustion) .	0·116 to 0·080	0·15
Silicon	0·009 „ 0·005	0·10
Sulphur	0·003 „ 0·008	0·05
Phosphorus . . .	0·001 „ 0·001	0·06
Manganese . . .	0·263 „ 0·441	0·50
Copper . , . .	——	0·10

Tube Co., a question arose as to whether there was a commercial supply of steel of that kind, and in reply to his enquiry, Mr. Lloyd, the chairman of the company, wrote :—"It is a certified analysis of a low carbon charcoal steel of basic quality, of which we use large quantities, but I should not take it as a standard; the silicon, sulphur and phosphorus are quite exceptionally low. We do not consider exceptionally low silicon a special merit. In English steel of good quality you would expect to find the phosphorus and silicon considerably higher." At a later date the firm submitted the following analysis of a harder steel :—

(Captain Longridge.)

TABLE 7.

	per cent.
Carbon	0·42 to 0.58
Silicon	0·30 „ 0·33
Manganese	0·52 „ 0·50
Sulphur	0·012 „ 0·012
Phosphorus	0·029 „ 0·029

In reply to a communication from the author in regard to Messrs. Krupp's analysis, Professor Turner wrote :—"There is no doubt Krupp's give a good composition for the purpose. The metal would be tough and quite high enough in tensity for all requirements. Higher carbons present more difficulty in working, and are more subject to alteration due to temperature in working, etc. I question if Krupp's do add copper. It is probably present in their metal, and may be regarded in such material as to some extent replacing manganese. It would not improve the running surface to any considerable extent, if at all. Phosphorus, sulphur and copper may be regarded in this analysis as unavoidable impurities not present in excess." Enquiries were then made as to the ability of the firms to supply a high carbon steel if such were preferred. To this the Weldless Tube Steel Co. answered :—"The highest carbon which we could supply would be approximately 60 per cent., and we consider this would be amply strong enough for the pressure you mention, namely, 320 lbs. per square inch with a comparatively thin wall." Messrs. Krupp replied by quoting for cold-drawn tubes of Siemens-Martin steel, having at least 7 per cent. of carbon, with a thickness of walls of $\frac{1}{4}$ inch, that is, an allowance of material of $\frac{1}{8}$ inch for machining. Both firms went into the question of price, Messrs. Krupp quoting roughly 41*s.* 6*d.* per cwt. for cold drawn tubes, Siemens-Martin steel with 0·15 or 0·35 per cent. of carbon, while for cold drawn tubes, Siemens-Martin steel of at least 0·7 per cent. carbon, the price per cylinder, 4 inches by $8\frac{1}{2}$ inches, worked out at a little over 4*s.*, the prices including delivery at any works in England. Both firms were prepared to supply sample tubes. It could not, therefore, be said that steel cylinders were costly or difficult to obtain either of low or of high carbon steel.

There was another interesting possibility, namely, that nickel steel might turn out the best of all materials. On 31st October, Mr. F. H. Lloyd, the chairman of the Weldless Steel Tube Co., kindly sent the following information, he (the author) having suggested to the Weldless Steel Co. the possibility that nickel steel might be useful :—"We have now rolled and tested a tube made from steel containing: nickel 3·76 per cent.; carbon 0·40 per cent. approximate; manganese 0·73 per cent. It turned and bored satisfactorily. We shall polish a short piece and send it you as soon as possible." The piece of metal exhibited at the Meeting was the piece referred to; it was an exceedingly good-looking metal. "The test piece cut from the rolled tube stood 43·58 tons per square inch with an extension in 2 inches of 24 per cent. The information I gave you, which you asked me to mention if I was unable to attend the adjourned meeting, was to the effect that considerable difficulty has been found in the application of nickel steel, from the fact that it has been found almost impossible to get a perfect thread in screwing, owing to a tendency of the metal, which is exceptionally dense and tough, to 'rag' or cut rough in screwing. One would naturally suppose that with metal that would take a perfect polish such difficulties could be overcome by using cutting tools of a different temper or shape or cutting at a slightly different angle of speed. I cannot say whether this difficulty would be the same with various percentages of nickel and carbon. There is no marked difficulty of this kind in the sample we are now dealing with, but it might appear if we were to put it to the test of cutting a fine thread. The sample piece turns and bears with a good surface."

He now wished to turn to two points which had been passingly mentioned in the discussion, namely, the bad wear and troublesome lubrication of the steel cylinders. He accentuated these points because he considered them as superstitions rather than facts. He did not deny that certain steel cylinders might have proved bad to wear and difficult to lubricate, but he did deny—or at least he could see no grounds for admitting—the general assertion that steel cylinders would not wear and could not be easily lubricated. The question of lubrication resolved itself into that of wear, because

(Captain Longridge.)
given a smooth surface with immunity from wear, there could be no difficulty with lubrication. It was the wear, the abrasion, the roughening of the surface, which led to lubrication troubles. What, then, were the factors which caused a metal to resist wear? First there was hardness or resistance to scratching; a hard smooth surface, offering the maximum resistance to scratching, presented also the minimum frictional resistance, the least wear. But as steel could be made with any degree of hardness, so it could be endowed, in that respect, with exceptionally perfect anti-frictional and wearing properties quite as good as those of cast-iron. In course of time, however, whatever be the material, it must wear. If that wear were uniform over the whole area, then the quality of hardness reduced the amount of abrasion to a minimum, and maintained the surface in its original excellent condition. But if from some want of homogeneousness, or from the presence of some hard foreign substance between the rubbing surfaces, irregular wear, scratches, or grooves were produced in the metal, then the very hardness which, in the first instance, was a merit, now became a defect, because it impeded the levelling down and filling up of the abrasions, thus increasing friction with further abrasion, and finally perhaps seizing. It was clear then, that in addition to hardness, something else was needed to improve the wearing property, by increasing the resistance to abrasion. That second factor was tenacity. In former days hardness and tenacity were, if not essentially, at least casually identified. About 1843 Wertheim experimentally concluded that the tenacity of a metal was proportional to the specific gravity, divided by the atomic weight. Some thirty years later, Bottone stated that the hardness of a metal varied in the same ratio. Hence it was surmised that as both properties varied inversely as the atomic volume or directly as the number of molecules in the unit space, they were at least causally united. Thus arose, or was fostered, another metallurgical superstition — that strength and hardness in cast-iron went together. He believed the credit of proving the fallacy of that conclusion belonged to Professor Thomas Turner, who in 1885 to 1887, by a series of very ingenious

experiments,* showed that while hardness and tenacity doubtless mutually depended on cohesion, and thus on the number of molecules in a given space, yet the two properties were physically distinct. Thus one might have a cast iron or a steel high in the scale of hardness yet low in that of tenacity, and *vice versâ*. That was a very important distinction. To resist the gradual uniform wear of normal friction, the attrition or grinding-away of the material in a fine, impalpable powder, hardness was the essential property; but to withstand an irregular pressure tending to strip off shavings or cuttings, to plough and furrow the material, tenacity was the important factor. Hardness was manifested by resistance to the force required to separate the smallest particles or molecules of the substance; tenacity was displayed by resistance to the force needed to separate the aggregated molecules or the mass as a whole. The best material therefore for wear and lubrication was that in which those two properties were duly combined. As in steel it was possible to combine these properties in almost any ratio, so there was no reason to contend that steel cylinders would be defective in wear and troublesome to lubricate. The difficulty which existed was purely experimental, namely, the cost and attention required to make the tests, which had already been made in the case of cast-iron, in order to determine the best proportions of hardness and tenacity for cylinder steel. Here it was that Mr. Lloyd's communication became of special interest, because the action of nickel was very peculiar on tenacity and hardness, and it was quite possible that nickel steel might, after all, prove the best steel of all. He did not lay much stress on the supposed spongy, absorbent nature of cast-iron as a factor favouring lubrication, nor on what might also have been suggested, the presence of graphite carbon; but he believed with Professor Turner that no other reason for the defects complained of need be sought than a faulty abrasion hardness and tenacity in the material. He hoped he had made the point clear, because the superstitions of bad wear and difficult lubrication of steel cylinders

* Transactions, Birmingham Philosophical Society, vol. 5, part II.

(Captain Longridge.)

were exceedingly prevalent, and very often appeared in the Press. He trusted that his observations might lead to a better appreciation of the capabilities of this promising material.

The PRESIDENT said the members had already expressed their indebtedness to Captain Longridge for his Paper in the vote of thanks accorded to him on the evening on which it was read. But he was quite sure he was only expressing the feelings of the members who had attended the meetings, when he said that their indebtedness had been greatly increased by the character of the discussion evoked by the Paper, and by the exceedingly interesting reply just given by the author. In addition to the remarks of the many members who had spoken at the last three meetings, a very large number of communications discussing the Paper had been received, and would be included in the Proceedings. Moreover Captain Longridge had promised to give a further written reply to the points raised in the written communications which had not come before the meeting. Bearing all these facts in mind he thought the Institution must add Captain Longridge's name to the list of those gentlemen who had, so very materially in the past, enhanced the value of the Proceedings of the Institution.

After the meeting, Mr. CHARLES T. CROWDEN exhibited drawings and a model of Butler's Petrol-Cycle Motor, which was an improvement on a motor for light vehicles, and was first patented in October 1884. It was a double-acting engine, consisting of two cylinders, each compressing the vapour and air mixture from the front end into a pressure chamber, whence it was admitted to the combustion chambers of the two cylinders during the first sixth portion of the outstroke; the supply was then cut off quickly and ignited. In the improved motor, as illustrated by the photograph and diagrammatic section and photographs, Figs. 37 and 38, Plate 80, the same cycle was used, but the quick cut-off of the mixture supply was obtained by a balanced rotative valve, Fig. 39, with two pairs of inlet and outlet port openings; this valve fitted gas-tight in a sleeve having two opposite portways, both in communication with

the combustion chamber. The valve was by this means entirely balanced, and only revolved a half-revolution per cycle of the motor. A second similar valve was also used to control the inlet and outlet of the mixture to and from the compressing end of the cylinder.

Explosive mixture was formed by a "spray" inspirator, Fig. 40, actuated by the induction of the piston and controlled by a throttle-valve, which was in the subsequent developments of this motor actuated by a large governor fixed on the countershaft. A modified form of the ordinary ball float was used to maintain a constant level in the oil cistern. The ignition was first on the magnetic principle, and, after experiments with an influence electric sparking machine, the induction method was adopted, worked by a bichromate two-cell battery controlled by an adjustable revolving commutator. In the experiments with this interesting motor vehicle, a wick carburator was at one time used, consisting of a box containing series of flat wicks dipping into flat tubes, open at their bottom ends to a benzoline reservoir; by this means it was sought to obtain a constant carburation, but in practice it was found that the more volatile portions of the spirit were absorbed and evaporated, leaving a residuum of heavier density. The spray inspirator was however found to give better and more constant carburation, and required very little adjustment.

Communications.

Mr. Henry Barcroft wrote, asking the author whether in the diagram, Fig. 9 (page 700) the gap between a and b extended with increase of revolutions and contracted with diminution of revolutions.

Mr. Herbert J. Bult wrote that there were one or two points in connection with the Paper, which seemed to the writer, as a chemist, to be specially interesting. The first, in connection with the fuel, concerned the replacement of petrol by alcohol, and the author

(Mr. Herbert J. Bult.)

suggested this as a problem for the chemist. Petrol, naptha, or as it was generally termed in the refinery, benzine, was used in several industries, which, however, did not require the total quantity that could be produced. At the present time its chief market was as a fuel for motors, and it was looked upon in the refinery more as a by-product. The production of crude petroleum for the whole world in the year 1901 was 27,000,000 tons. The benzine it would be possible to obtain from this quantity of oil could not be accurately estimated, as no two wells produced exactly the same grade of oil, and the products varied according to the method of working. Taking it roughly at 5 per cent., the quantity produced would be 1,350,000 tons of benzine suitable for motor fuel; and in order that alcohol might compete with petrol, it must be produced at a cost which was no greater than that of the carriage of petrol.

Reference was made (page 742) to a communication from Messrs. Crossley Brothers, in which they stated they were unable to use the same class of lubricant for the cylinders of oil-engines as they were in the habit of using for gas-engines, owing to the deposition of carbon on the piston rings. This, it was understood, referred to mineral lubricants and, he thought, might be accounted for by referring to the composition of the fuels used in the two types of engines. Coal-gas contained about 40 per cent. of hydrocarbons and 46 per cent. of hydrogen, this latter always being present in fuel gases. On the other hand, kerosene and other petroleum fuel oils did not contain free hydrogen. It was known that hydrogen and carbon combined when heated to the temperature of the electric arc, and this combination would be more easily brought about if these substances were in the nascent condition. When mineral lubricants were highly heated, they decomposed and deposited carbon, and this being in the nascent state, would combine with the hydrogen in the gas, while, as there was no free hydrogen in oil fuels, the carbon would be deposited.

The cause of premature ignition taking place in oil-engines, when lubricated by ordinary gas-engine oil, might be explained by considering that all hydrocarbons, of the several series found in petroleum, dissolved one another. In the refinery, he had found that

for cleaning tanks in which heavy oils, such as astatki or mazoot had been stored, a quicker and better solution of the oil was obtained, not, as might be expected, by the use of as light a solvent as possible, but by one that more nearly approached the composition of the heavy oil, as a solar oil or spindle oil distillate, and this held good until the viscosity of the solvent interfered with the mixing. Referring again to the fuels, the chief constituent of the hydrocarbons in coal and other illuminating gases was methane. Fuel gases, as a rule, did not contain hydrocarbons. Kerosene consisted for the greater part of higher members of the paraffin and naphthene series; and tridecane ($C_{13}H_{28}$) of the paraffin, and α — decanaphthene ($C_{10}\,H_{20}$) of the napthene series might be taken as typical examples. It would be seen, therefore, that the vapour of kerosene would more readily dissolve the lighter hydrocarbons contained in the lubricant than would a fuel- or coal-gas. The small quantity of lubricant, thus vaporised, would be decomposed by the high temperature existing in the cylinder, and would then readily ignite.

Mr. W. Hemingway wrote that, unfortunately for the title, "Oil Motor Cars of 1902," the use of oil for such a purpose appeared to have been overlooked or omitted from the Paper. "Spirit" should be substituted for the word "oil," or the word "oil" deleted.

In the following remarks the figures given for comparison were approximations to the exact scientific ones sufficiently near for commercial purposes, the subjects not mentioned, but equally important with those treated, were left out from want of space only. From the description given the author's engine differed materially, and was a great step in advance of those of the same cycle already in use. The cycle was exceedingly simple, but the engine was not. The use of the front end of the cylinder for an air-compressor necessitated the use of a piston-rod with crosshead and slide, cylinder cover, gland and stuffing-box, all undesirable features in an internal-combustion engine, and increase in the total height or length of the engine by at least the length of the stroke, if the standard length of connecting-rod was to be used; there were double the number of valves to each cylinder, and extra mechanism for operating

(Mr. W. Hemingway.)

the valves. Special provision must be provided in the base chamber to facilitate getting at the glands for adjustment and packing, and extra special precautions must be taken to ensure proper lubrication in the new frictional parts; more friction ensued, and there were heavier moving parts (reciprocating), with greater inertia. All of these items would require regular and constant attention, over and above that necessary with the ordinary type, and would introduce further certain sources of trouble and possible breakdowns. Assuming the same brake-power was given off in both cases, the prime cost of a two-cylinder engine of this type would equal that of a four-cylinder of the ordinary Otto: the working expenses, fuel, and lubricants would not be any less, and the repairs and up-keep greater than a four-cylinder Otto; and the regular and constant attention required considerably more.

Castings.—The two compositions for castings put forward in the Paper should come under the heading of manganese steel castings, the manufacture of which had hitherto been confined, he believed, to one or two firms, and solely for purposes requiring much heavier castings than those for motors; it would be of interest to know if the intricate small motor castings came out successful in this material. Common cast-iron, more especially that used in the ordinary jobbing foundry, was exceedingly variable and indefinite in its nature, and on no account should be used for motor castings. When these were required, extra precautions must be taken in moulding, special blows should be made with a first-class brand of pig and wrought scrap, the compositions of which were known or could be definitely ascertained. This mixture should first be run into pigs, then melted a second time before being used for castings. The following was put forward as a good average composition for cast-iron suitable for motor cylinders and pistons, giving a tensile stress of about 25,000 lbs. to 30,000 lbs. per square inch.

Silicon		1·000	to	1·300
Sulphur		0·066	,,	0·050
Phosphorus		0·170	,,	0·175
Carbon	Graphitic	3·40	to	3·32
	Combined	0·40		0·60
		3·80		3·92

For piston-rings or pots, slightly harder and more elastic metal could be used; for guaranteed castings of this description a higher price than usual must be paid. This in the end would work out cheaper than the usual method with its large proportion of wastrels.

Valves.—Velocities of 80 feet per second for induction and 100 feet per second for exhaust were put forward, but logical reasoning would reverse these figures. Highly heated gases travelling through a passage tended to cut and score the walls of that passage, the greater the velocity the greater the tendency, therefore why should a highly heated gas be made to travel through a passage at a considerably higher velocity than ordinary air and vapour at a temperature at or slightly above freezing point. To approximate equal velocities, the exhaust should have about three times the area of the induction.

Diagrams.—The diagram, Fig. 8 (page 697), typical of all coal-gas explosions was perfectly useless, and apt to be misleading for spirit-motors. The time of attaining maximum pressure was there shown at 0·26 second; in a more recent diagram taken by Mr. Petavel's gauge with the most explosive mixture of air and coal-gas, the time of reaching maximum pressure was less than half that shown in the Paper. In a petrol-motor working at 780 revolutions per minute the time of a complete half-stroke was 0·0384 second, or only one-seventh that of the diagram shown.

In "The Engineer,"* a description was given of Mr. J. E. Petavel's new recording pressure-gauge; from its extreme sensitiveness it should be of exceptional value in connection with petrol-motors to obtain definite and accurate records, which up to the present had not been possible, and it was to be hoped for the credit of the motor industry that such records should soon be forthcoming.

Tables 1 and 2 (page 699) on the diagram, Fig. 9 (page 700), also were of no use for studying the problems of combustion in petrol-motors as used on cars. At least in every case quoted the revolutions were less than half and the stroke double that of petrol-motors. In the diagram of a petrol-motor the expansion-curve would be considerably steeper and the average pressure considerably modified.

* "The Engineer," 10 October 1902.

(Mr. W. Hemingway.)

Petrol.—Was it not a fact that very little information respecting petrol was to be obtained, not only in this but in any other country? The maximum explosion pressures, and the times of attaining the same, the rates of cooling, the chemical composition, whether it was a single definite hydrocarbon or a mixture of two or more, its physical attributes, vapour density, latent heat, expansion, temperature of inflammation, etc., were all equally obscure. The admission of water in the cylinder of a petrol-motor opened a large field for discussion. Herein the exact chemical composition of petrol was of importance. In the Paper it was assumed to be pentane C_5H_{12}. If it were so, incidents that continually occurred in practice showed that there were proportions of other hydrocarbons mixed with it; to mention one only, it was quite common to find the nozzle of the jet carburettor frozen up, and small pieces of ice could be taken out. These apparently small fragments of ice quickly melted and evaporated, the vapour taking fire with a match; probably this ice was a mixture of benzine (which froze at 0° C.) with minute quantities of water (petrol being deliquescent). In considering the phenomena that occurred when water got into the cylinder with petrol, the following data might be of use:—

(*a*) It was well known that water brought into contact with incandescent carbon was decomposed. Was there the necessary incandescent carbon in a petrol cylinder, and if so, how did it arise? He did not think this was possible.

(*b*) Did the water, with or without the presence of incandescent carbon at the high temperature of the cylinder, decompose itself alone, or the petrol alone, or the petrol and itself at the same time, and if so what were the critical temperatures at which the reactions took place?

By the use of *petrol alone* one obtained the following result. Composition C_5H_{12}. Specific gravity 0·680. Boiling point 38° C.

One part pentane required 3·55 parts oxygen for combustion, and evolved 12425·0 Th.U.

With petrol and water various different results could be obtained as follows:—

(1) *Petrol intact* and water only decomposed to form water-gas (Dowson Gas?); then, treating water-gas as a definite compound of the formula H_4CO, as given in Paper—

$C_5H_{12}+H_4+CO$. . . . . Heat evolved = 8837·0 Th.U.

(2) *Petrol intact* and water only decomposed, and treating the mixture as equal quantities of the gases carbon monoxide, hydrogen, and petrol—

$C_5H_{12}+H_2+CO$. . . . . Heat evolved = 16439·0 Th.U.

(3) *Petrol and Water, both decomposed* in accordance with formula given in Paper—

$C_5H_{12}+H_2O = C_2H_6+CO+C_2H_4+2H_2$. Heat evolved = 9954·0 Th.U.

(4) Petrol and Water, both decomposed in accordance with formula given in Paper—

$C_5H_{12}+H_2O = C_4H_{10}+CO+2\ H_2$. . Heat evolved = 9954·0 Th.U.

(5) Petrol and Water both decomposed as per formulæ—

$C_5H_{12}+H_2O = C_4H_8 + C + 3\ H_2 + O$. Heat evolved = 12866·0 Th.U.

(6) $C_5H_{12} + H_2O = C_4H_{10} + CH_4+O$. Heat evolved = 12866·0 Th.U.

(7) $C_5H_{12} + H_2O = C_5H_{12} + H_2 + O$. Heat evolved = 12866·0 Th.U.

Assuming in the explosion that the whole of the oxygen in the cylinder was consumed, the first solution could at once be placed on one side.

In the second case the assumption was that there were equal volumes of the three separate gases, petrol, hydrogen, and carbon-monoxide. This was an impossibility however, for the volumes of gases liberated must correspond to the chemical composition due to the limited minute quantities, short time, and confined area in which decomposition took place. This solution, although it gave great additional heat, must also be placed on one side.

In cases 3 and 4 although decomposition of both petrol and water took place, the equivalent volumes of gases must be in strict chemical proportions, only for the same reasons as above; the total heat generated would be less than with petrol alone, because one atom of oxygen was already combined in the form of carbon-monoxide, and merely diluted the charge.

In the fifth, sixth, and seventh cases, wherein the oxygen was wholly free from combination, the residual gases were left proportionally richer from a combustible point of view (in fact, the richest possible from the ingredients involved), and at the same time the necessary oxygen required was provided to consume the hydrogen

(Mr. W. Hemingway.)

freed from the decomposition of the water, which otherwise would not be available from external sources. In each of these cases there was a very slight increase in the heat evolved over petrol alone, but not of any material moment or sufficient to account for the effects produced by the water getting into the cylinder in the case cited. The decomposition of either or both the petrol and water, and their total simultaneous combustion in the cylinder would be inadequate to account for the phenomena observed.

On the other hand, there was still another important factor to be taken into consideration. It was advanced in the Paper that the greater inflammability of water-gas was due to the small quantity of oxygen required for combustion. This was hardly correct; each gas, even with the most explosive mixture, must be raised to a certain definite temperature before it would inflame, such temperature depending upon some physical quality or constitution of the gas, and not merely the amount of oxygen required to consume it, for instance carbon disulphide (mentioned in the Paper as a proposed enricher of petrol) would inflame at the low temperature of 268° F., whereas ordinary coal-gas required a temperature of about 1,300° F. before it would inflame. The converse of this was also true, no gas being inflammable above a certain temperature even with the best possible explosive mixture. This limited range for the combustibility of gases was far smaller than generally supposed. Experiments made by Bunsen showed that only one-half of a charge of the most explosive mixture of either carbon-monoxide or hydrogen would inflame at a temperature of 2062° F.; the temperature at which the whole charge would inflame was not stated. None whatever would explode in an atmosphere of oxygen at a temperature of 1543° F., or in an atmosphere of carbon-dioxide at 3220° F., the latter case being the condition of the cylinder in an ordinary motor after firing.

The inference to be drawn from these experiments was that under no circumstance must the temperature of the contents of a cylinder exceed about 1800° F. before the whole of the charge was consumed. If it did so, the balance of combustible gas would be wasted in the exhaust, or take fire and burn in the cylinder or ports, when or where the temperature had been sufficiently lowered. This might

take place without any actual decomposition of the fuel. In addition the high temperature reached by the combustion of part of the charge might be sufficient to decompose the balance and produce the same effects; either eventuality or both would quite account for the hot exhaust, carbon deposits, premature ignition, burning of the valves, and the occasional explosions in the silencer.

The problem of how to get the best results from a spirit motor, wherein the fuel was liable to decomposition, was to keep the charge before firing at the lowest possible temperature, in order to get the whole of the charge fired before the temperature of the gases had reached about 1800° F., to prevent the sudden rise of temperature retarding the ignition of a portion of the charge, thereby wasting fuel and probably burning the valves, or decomposing the balance with a similar result; also to keep the temperature (and pressure) as high as possible after explosion, and during the working stroke, consistent with having large valves and getting rid of the exhaust expeditiously to prevent undue heating of the water jacket, and to give a relatively longer time for the cylinder and contents of compression space to cool between the strokes.

Alcohol.—The use of alcohol enabled one to approach nearer to these conditions than petrol. This might be briefly shown as follows:—

Absolute Alcohol $\left.\begin{matrix}C_2\,H_5\\H\end{matrix}\right\}O$.

Specific Gravity = 0·809.

Proof Spirit containing 50% Water S. G. = 0·920.

Boiling Point 78·4° C.

1 part Alcohol required 2·087 parts oxygen and evolved 7180 Th.U.

In comparison with petrol, and the volume of the cylinder the same, 1·7 parts more alcohol (or, in the liquid state, $1{\cdot}7 \times \frac{0{\cdot}680\ (\text{S.G.})}{0{\cdot}920\ (\text{S.G.})} =$ 1·267 as stated in the Paper from actual use) could be consumed per charge, in order to get the most explosive mixture, and utilize the whole of the oxygen. In the best commercial alcohol (proof spirit) there was at least 50 per cent. of water, which on combustion formed a huge absorbent of heat (latent heat of steam alone requiring

(Mr. W. Hemingway.)
536 Th.U. without any visible increase in temperature), being instantly converted into superheated steam, acting in this case in the capacity of a gas, and not a saturated vapour (if it existed in the latter form, taking the temperature into consideration, its pressure would be enormously greater than the actual). The large proportion of steam produced was an important feature, for from its great initial latent heat (two and a half times greater than alcohol, and almost six times greater than petrol) and the great avidity with which it re-absorbed the heat liberated by the cooling and expanding gases (the ratios of cooling of the vapours might be taken approximately the same as the latent heats), it would form a reservoir or equalizer of heat and pressure, preventing undue temperature at first and too rapid cooling or reduction of heat and pressure afterwards, thereby tending to raise the average pressure throughout the stroke.

It was well known that at very high temperatures, due to the increase of specific heat, the capability of gases to do work (otherwise increase in pressure) by the absorption of a definite quantity of heat was not nearly so large in proportion to the work produced by the absorption of the same quantity of heat at a considerably lower temperature. The physical conditions mentioned above, and attached to the use of alcohol, were all in favour of attaining instantaneous and complete combustion of the whole of the charge, and utilizing the heat evolved in the cylinder itself thereby converting a larger proportion into work. Taken together it meant less waste of fuel, higher efficiency and a cooler running and more elastic engine. With the use of alcohol as fuel, he had never heard of any case wherein the temperature of the cylinder had reached the point sufficient to decompose the water or fuel with its subsequent troubles. While studying this question, the relative expansion ratios of various substances might be useful (*see Table* 8).

Considering the recent restrictions against carriage of petrol, and that its manufacture was a monopoly restricted to two firms, and the chief drawback against alcohol was the price, and the necessity of denaturising it (no substance at present being found wholly satisfactory for this purpose) to comply with the revenue authorities, he would suggest the use of ether for motor work.

TABLE 8.

	Cubic inch.	Cubic inches of Vapour.	Latent Heat. Thermal Units.	Range of Explosibility.
Water . . .	1	1698	536	——
Alcohol . . .	1	567	208	9·7
Ether . . .	1	246	90	5·0
Petrol * . . .	1	240 (8173?)	88	2·5

Ether is practically alcohol with the water eliminated. It could be made direct from alcohol or from all the numerous substances used for making alcohol (potatoes, grain, etc.), and could be manufactured universally by ordinary distillers and brewers, in every country, it was not drinkable, and would no doubt be free from revenue restrictions. As a fuel for motors, it was a very happy medium between alcohol and petrol, possessing the good points of both without the drawbacks—

Ether $= \left.\begin{matrix} C_2O_5 \\ C_2O_5 \end{matrix}\right\} O$. Specific gravity = 0·736. Boiling Point 34·5° C.

1 part ether only required 2·6 parts oxygen, and evolved 9,100 Th.U.

It would not freeze at any temperature. From these figures it would appear possible to use it in the present petrol carburettors without alteration, the boiling point being practically the same as petrol. In comparison with petrol, and with equal cylinder volume, 25 per cent. more ether could be consumed. The heat generated would be about 16 per cent. greater than in the case of absolute alcohol, and 27 per cent. lower than petrol. The question arose, would the general reduction of temperature in the cylinder compared to petrol be sufficient to prevent the critical temperature of decomposition being reached if water were added to the fuel. If

* The above figures were worked out from the pentane formula and vapour density; in the Paper the footnote (page 689) gave the expansion of petrol as 1 drachm into 1,300 cubic inches of vapour =8,173 cubic inches of vapour to 1 cubic inch of petrol. This expansion was nearly five times greater than water, and evidently erroneous.

(Mr. W. Hemingway.)

this were the case, and indications appeared to be favourable, material improvement over both alcohol and petrol motors could be expected. At the worst if water could not safely be used with ether, the results from ether alone would practically be equal to those from petrol, for the lower cylinder temperature would be accompanied by more perfect combustion.

The present market price of ether was comparatively great because of the small demand, but the enormous possibilities ahead from the enlarged market it would open in this country, and in every part of the world (where it was impossible for petrol-motors ever to be introduced for want of fuel) for heavy traction, freight, and passenger service road and rail, launch and boat work for river, canal, and coasting service, life-boats, and tenders to larger vessels, etc., and the cheapness at which it could be made, would warrant giving it a fair trial.

Enrichers of Petrol.—Was the idea to lower the temperature of the point of ignition, or was it to produce a higher temperature with consequent increase in pressure? The first was of doubtful benefit, if any. The second would be useless without a method was simultaneously introduced for direct conversion into work; temperature was here used as perfectly distinct from heat. On this point the following note might be of service which held true, although it would be doubted by many. "In an internal-combustion motor with constant cylinder capacity working under ordinary conditions (the incoming charge being ordinary air sucked in at atmospheric pressure), and supposing the whole of the oxygen in the charge is consumed in the best possible manner, the maximum total heat that can be generated would be approximately the same, no matter what fuel was used, so long as the fuel came under a series of analogous compounds, such as the typical hydrocarbons in every-day use (containing carbon, hydrogen, and a small proportion of oxygen (alcohols)), for instance, coal-gas, acetylene, petrol, alcohol, ether, benzene, etc. The minimum or actual heat generated would be somewhat varied by circumstances. The temperatures and pressures would also differ considerably." Petrol produced more heat than any other hydrocarbon available (hydrogen, marsh-gas,

ethane (all gases), butane (liquid) excepted), therefore any idea of enriching it was hopeless and a mere waste of money, unless resort was made to the addition of substances containing large proportions of oxygen, which would at once raise it to the category of highly-dangerous explosives prohibiting it from ordinary daily use. Any substance added to petrol should partake of the effects of water in alcohol, for there is too much heat generated already not converted into work, in addition to fuel wasted and going away unconsumed through that surplus heat.

Lubrication.—There was no doubt equally as much to be said about lubricating oils, chemical, physical, and mechanical, as about the fuel used for driving the motor. Lubricating experts would no doubt give valuable information when they had fully grasped the conditions of the problem, about which there appeared some difficulty.

The conditions of a cool-running engine were favourable for the lubricating oil which was certainly more readily decomposed than the fuel, owing to its more complex constitution, and also in nearly every case being a mixture of several distinct but analogous hydrocarbons, the close proximity of which on exposure to the high temperatures involved conduced to a re-arrangement of molecular structure; in the new combinations it was almost a certainty that the flashing point of some individual combination would be reached, so upsetting the equilibrium and perhaps flashing the whole.

Physical laws played an important part in both questions of flashing and lubrication, the chief ones brought into use were the laws of capillary attraction and surface tension; the oil was first fed between the cylinder and piston, and by capillary attraction was distributed all round each where the surfaces were in contact, when the piston traversed the cylinder, by the same laws, a very thin or capillary layer of oil was left, wherever the two had been in contact or approximately so. This layer of oil clinging to the walls of the cylinder would be of the same temperature. In ordinary working conditions the flash of the explosion was only momentary, and the surface tension of such a capillary layer of oil where exposed (approaching the force of cohesion) would be sufficient to preserve

(Mr. W. Hemingway.)
the surface intact; such a capillary layer of oil being diathermanous or transparent to the heat equally with the cylinder walls of which it really formed a part, would allow the heat to pass through to the walls and thence to the water-jacket without any material increase in its own temperature. Should the layer of oil be so thick as to exceed a capillary layer either by accidental extra supply or surfeit of oil, or by the use of a too thick oil, the ordinary laws came into action, and the force of the explosion would be sufficient to overcome the surface tension and perforate the layer of oil and detach a portion, which would at once be flashed into vapour by the fierce heat and exploded. The internal appearance of a petrol motor did not give much evidence to support the idea that the oil was sprayed all over the interior in a similar manner to that in a steam cylinder when carried by a steam jet, for any part not actually in rubbing contact was usually free from any suspicion of oil when the engine was running satisfactorily; if the oil got sprayed through a too liberal supply, etc., it was usually not long before the engine pulled up, either from sticky valves or failure of the electric ignition. In addition to the high flash-point oils mentioned in the Paper, he would add those of Messrs. Engelbert, one of which was higher still:—

							Rape 100.	
	Sp. Gr.	Open Flash.	Close Flash.	Fire Test.	Ash	Free Acidity.	Viscosity 200° F.	Viscosity 250° F.
F.F.C.	0·892	540	570	630	Nil.	Nil.	27·8	13·4
S.S.	0·901	576	620	676	Nil.	Nil.	43·6	18·8

With the question of axles, springs, frames, bodies, coils, etc., and the general lament that they were not procurable in England he did not agree; it would be equally applicable to lament that motors also could not be procured from the ordinary engineers' shops. Motor companies were formed with the alleged and avowed intention of making motors, parts, and accessories. Any British motor company worthy of the name should manufacture and produce in this country all the important and special parts themselves, minor parts only, such as bolts, nuts, washers, etc., requiring no special knowledge for their production, being procured outside their own works. Given

the opportunity, there were many engineers in Great Britain fully competent, capable, and ready to do the whole of the work, equally as well as those of any other country, and there was also an ample supply of home-manufactured and raw material to draw upon for the purpose. With the decrease in trade in other directions, the present moment was the most opportune for mechanical engineers and British engineering firms to take up seriously the manufacture of motors, before the Americans and Germans who had just awakened to its value and importance got control of the market. That there was a good opening and vast room for improvement in the application of the knowledge about motor-cars already acquired was evident and emphasized by the efficiency results given by the Automobile Club in the recent 650 miles reliability trials. In climbing Westerham Hill the actual horse-power given out at the wheel-rims compared with the brake horse-power of the motors, as specified by the makers, was as follows :—

8 H.P. M. M. C. Voiturette, 37·5 per cent. 10 H.P. Wolseley, 50 per cent. 22 H.P. Daimler, 59 per cent. 8 H.P. De Dion, 50 per cent. 6 H.P. De Dion, 53·3 per cent. 15 H.P. Panhard, 65·4 per cent.

$$\text{The H.P.} = \frac{\text{Vertical height of hill in feet} \times (\text{Weight of car and load in lbs.} + 40 \text{ lbs. for every ton of total weight})}{\text{Time in minutes} \times 33{,}000.}$$

Mr. John Johnston wrote that, like the author, he was a believer in the ultimate triumph of the impulse-every-revolution engine, and also in the use of heavy oils. He had been doing his best to bring about such a result. Regarding the author's proposed engine, it was rather a risky proceeding to criticise the design as some had done, for he had long since learned that it was impossible to know what an internal-combustion engine—especially an oil-engine—would do until it was tried. He thought that the clearance losses between the pump and the work cylinders would be considerable, and would lower the efficiency of the engine; also that the presence of so large a quantity of exhaust gases would keep down the effective pressure and necessitate a bulky engine. He had never in his experience found that the presence of exhaust gases in a cylinder had done other than lower the effective pressure, and he had even introduced them

(Mr. John Johnston.)
along with oil-gas, in order to soften the explosion and reduce shock in the cylinder caused by the too rapid combustion of a mixture of oil-gas and air; this it effectually did, but at the same time there was a loss in pressure.

In this connection, it was the sudden explosion that caused an oil-engine to give off the metallic chink, which Professor Robinson (page 780) spoke of as having been stopped by introducing water into the cylinder, also which caused the sharp loop on the indicator diagram, as illustrated in the Paper. This loop was due in a large part to the velocity of the indicator pencil, causing it to overshoot the point to which it would be carried by pressure only, and he would suggest to Professor Burstall that he would find this the explanation of the apparent difference between the maximum and mean-pressure of an oil- and of a gas-engine. The gas-engine explosion was gentle, and did not cause the indicator to overshoot the mark; the oil-engine explosion on the other hand was violent, and the consequent momentum of the indicator pencil made it register a false pressure as described.

Regarding Mr. Beaumont's criticism of the impulse-every-revolution engine (page 764) as being more complicated than the Otto cycle-engine, he would remind him that, on the contrary, it was possible to make one much simpler than an Otto engine, namely, the "Day" engine for example, which required no valves at all. He knew that he himself would be told that such engines were very wasteful of fuel, but on an engine of his own construction, which however had one automatic valve, he had obtained a brake horse-power with $\frac{7}{8}$ lb. of oil. This was an engine having a cylinder 4 inches diameter by 6 inches stroke, and he had as yet to discover the Otto engine of that size which would do better.

The next point upon which he wished to touch was the question of valves, positive versus automatic, and he might say that from his own experience, any one who fitted up mechanism to work the inlet valves of small petrol-motors positively expecting to get a better result than others obtained with automatic action would be sadly disappointed. Four years ago he had been associated with the late Mr. Capel, of Dalston, and assisted him in producing a motor, in the

design of which he started with the idea that the use of positive inlet valves would give them a better result than any one else had obtained with automatic. The engine was constructed and tested, and during testing the setting of the valves was tried in every possible position to see which would give the best results. After this was done he persuaded Mr. Capel to let him try the engine with automatic inlet valves, with the result that he obtained nearly one-fourth of a brake horse-power more, and this was on an engine having two cylinders of 3 inches by 5 inches stroke. On these high-speed engines the automatic valve did not close too quickly, as Captain Longridge suggested; in fact he had to tighten their springs over and over again to make them close more sharply, and prevent a blow back of charge due to the returning movement of the piston, which proved that the trouble was not in too quick closing.

Regarding the late opening of the valve, this served a useful purpose not generally understood. The formation of a slight vacuum in the cylinder, before the valve opened, expanded and cooled the exhaust gases remaining in the cylinder, and extinguished any live flame before the inrush of a fresh charge, which would be fired by any lingering flame. This action therefore enabled a higher speed to be run than would be possible with a positively operated valve, unless the timing of it was made late, which would of course take away all value of positive working. He had had this point brought home very forcibly to him in his own experiments with the impulse-every-revolution engine, of which he had tried two kinds. In the first the fresh charge was forced into the cylinder, driving the exhaust gases out before it, and in the second the exhaust gases were sucked in by means of a vacuum, drawing in the fresh charge behind them. In the first engine, if he tried to work it much above 200 revolutions per minute, the back-firing became so bad as to bring the engine frequently to a standstill; but in the second engine he could run it at 800 revolutions with the greatest of ease without a single back-fire. This of course corresponded to 1,600 revolutions on an Otto engine.

The vacuum class of engine was introduced into this country about sixteen years ago, and he could not imagine why it did not

(Mr. John Johnston.)
prove a commercial success. He had, however, required to make alterations in detail from anything then published which he found necessary for success. Regarding the Napier form of valve, he did not attach much value to it, as he would sooner enlarge the diameter of a valve than increase the number of faces. To multiply valve faces was to multiply troubles. The author called the use of an automatic inlet-valve a crude arrangement, yet he proposed to use one on his own engine, which was surely not a very consistent proceeding.

On the question of carburetting and the use of positive feed, he again disagreed with the author's opinions. Any one who adopted a so-called positive feed in preference to a suction one, would find it anything but all that he desired. Positive feeds must be either pumps or measuring devices, and at high speeds they would not work regularly at all. Measuring devices were also unreliable at speeds over 300 revolutions per minute. Above that speed they would not fill and empty themselves with sufficient rapidity; this he was certain was the reason why the Gobron-Brillié engine used a large number of measuring cavities on the circumference of a wheel, so that the motion of the device was relatively slow compared with that of the motor itself. He was absolutely certain, from direct experiments, that an engine with a carburetting and mixing device, having a fairly strong suction to ensure good mixing, would work better than one in which the charge was got into the cylinder without previous carburetting and thorough mixing with the air. All that was necessary to prove this point was the judicious use of an indicator.

On a previous occasion * he had stated that he had transformed ordinary gas-engines from bad working into good working motors, by the simple addition of a mixer in the inlet port. In fact he had been enabled to remove the timing-valve from a gas-engine through adding a mixer. He thus obtained a perfectly regular diagram with the charge well mixed and the timing-valve removed, when he could not get it with a badly-mixed charge and a timing-valve; to get a

* Proceedings 1901, page 1135.

well-mixed charge, however, a certain amount of fluid resistance was an absolute necessity in the inlet passages.

At different points in the Paper the author advocated a positive feed, and governing by controlling the amount of exhaust gases discharged. He would therefore like to ask him how he proposed to work the two together; if he varied the exhaust he varied the amount of fresh air admitted, while at the same time he measured in a constant quantity of oil. He was afraid that if he attempted to so work an oil-motor he would soon find it refuse to do work under such conditions. Governing on the throttle might not be theoretically correct, but the question was not so much that of a few gallons of petrol as of reliability and durability. The first repair bill might swallow up the savings of the theoretically correct engine several times over. The "Capel" engine, which he had previously mentioned, was designed four years ago, and had throttle governing; the ignition was automatically controlled by a ball governor moving a diagonal contact-piece, as advocated by the author. Both inlet-valves were held by one stud, and the compression was also applied and released by the governor in starting and stopping the motor. The throttle governing was, however, not exactly volume governing, as the throttle was arranged to act suddenly, and completely cut off the supply, the pistons then forming a vacuum. He, however, found that the strength of the vacuum caused the throttle to stick, and the engine to work irregularly, so he had to drill a small hole through the inlet-pipe between the throttle and the inlet-valves to allow air to enter and partly break the vacuum. On examining a recently imported up-to-date French car a few weeks ago, he was pleased to find the governor arranged to work in exactly the same manner, and the same small hole drilled.

Regarding the author's increased expansion gear, he himself had proposed a somewhat similar arrangement to Messrs. Priestman, of Hull, about seven years ago, and it was objected to by them on the points of cost, and wear and tear. The idea and action were the same, but the detail was different. He had proposed to mount an eccentric on the crank-pin, and to fix the connecting-rod to the

(Mr. John Johnston.)
eccentric strap, the eccentric being revolved once for every two revolutions of the engine-shaft, by means of a sun-and-planet motion.

In regard to the question of water in the cylinder, he had always found the presence of water in the cylinder of the Otto cycle engine, whether due to water leaks or otherwise introduced, instead of advancing the ignition would retard it, and often would prove fatal to getting any ignition at all; but on one of his own engines he had introduced water with successful results. By feeding in a certain quantity every stroke, he could run the engines as long as he pleased, without requiring any jacket water at all; it was not, however, introduced through the admission-valve or into the combustion chamber, but through the wall of the cylinder near the forward end of the piston-stroke, so that it was sprayed over the back of the piston, and on the back stroke was distributed over the cylinder walls; the power of the engine was thus increased nearly ten per cent. His theory of its action was that it took up the heat which otherwise went to the water-jacket; this heat turned it into steam, which consequently increased the total volume of the charge. He was certain that the water was not decomposed, for on discharging the exhaust through a long horizontal exhaust-pipe, the water was re-condensed and could be collected at the end. Some that was collected had just a thin film of oil floating on the surface. The use of water was not carried into practice, because of the nicety of adjustment required being likely to cause trouble. This experiment was carried out five years ago.

M. R. Mathot (Brussels), who has established in Belgium a special laboratory for the testing of engines, writing in French, offered as a useful addition to the Paper a method of comparing or classifying motors on certain standard data. He had been led, in the course of numerous experiments on all kinds of motors, to look for a simple and speedy method for comparison, and he suggested the following:—

The elements of the problem were these:—

A. The manufacturer indicated—

The power in effective H.P. that the motor was capable of developing: F.

The number of cylinders: K.

The number of revolutions per minute: N.

The diameter of the piston or pistons d in centimètres, from which the area, S, expressed in square centimètres, could be calculated.

The stroke of the piston or pistons: C.

B. There remained an unknown quantity: the mean pressure P on the piston during a whole cycle. Applying the formula—

$$F_1 = \frac{S \times C}{60 \times 75} \times \frac{N}{2} \times P \qquad (1)$$

which gave the *indicated* power, when an explosion took place for each complete cycle, with full charge.

In order to get at a simple formula for the comparison of motors greatly differing in dimensions, number of cylinders, and speed, it would be well to apply the above formula to the case of one cylinder and a number of revolutions corresponding to 75 "kilogrammètres" or 1 Eff. H.P.

In the formula (1), F_1 corresponded to *indicated* H.P. It might be admitted that the mechanical efficiency of high-speed motors was not far from 80 per cent. Thus the formula became—

$$F_2 = 0,80\ F_1 = \frac{0{\cdot}80 \times S \times C}{4500} \times \frac{N}{2} \times P;$$

$$F_2 = \frac{S \times C}{11250} \times N \times P \qquad (2)$$

F_2 representing the *effective* power of a certain motor, with one cylinder, running at a speed of N revolutions per minute, the explosions of which developed at each cycle a mean effective pressure P.

If in formula (2) one took $N = 1$ and $P = 1$ kg. per cm^2, the result would be—

$$a = \frac{S \times C}{11250} \qquad (3)$$

"a" being the effective power developed by the motor at each revolution of the shaft with an effective pressure of 1 kg. per square

(M. R. Mathot.)
centimètre of piston area; the mechanical efficiency of the motor being supposed equal to 80 per cent., "a" might thus be called the "*modulus of power*" of the motor.

The effective power of the motor F being indicated by the manufacturer for K cylinders, one had—

$$F = FK_2 \quad F_2 = \frac{F}{K},$$

the number of revolutions per minute "n" producing *one effective* H.P.

$$n = \frac{N}{F_2} \text{ or } n = \frac{KN}{F}. \tag{4}$$

The formula (2) then became—

$$1 = \frac{S \times C}{11250} \times \frac{N}{F_2} \times P,$$

$$\frac{1}{\frac{S \times C}{11250}} = nP \text{ or } \frac{1}{a} = P. \tag{5}$$

n was determined by formula (3)

$\frac{S \times C}{11250} = a$ could be calculated, since the diameter D and the piston stroke C were known. It followed that the mean pressure P, which was to be obtained, was determined by the data of the problem themselves.

Formula (5) $\frac{1}{a} = nP$ being established, its application for the purpose of comparing motors with each other would be explained.

The motors were classed according to the values of n, that is, according to the number of revolutions per minute which they had to run in order to develop *one effective* H.P. and in each class a certain latitude for n was admitted, for example:—

1st	class	$n = 90$ to 140
2nd	„	$n = 140$ to 190
3rd	„	$n = 190$ to 240
4th	„	$n = 240$ to 340
5th	„	$n = 340$ to 440

Such a classification was of course arbitrary, and could be modified to suit various cases.

In each class the motors were also classed according to their "modulus of power," from the lowest to the highest.

It was obvious that if two motors did the same amount of work at the same speed, the one that produced it with the lowest "modulus of power" was the better one. Finally, the values of P allowed of checking the accuracy of the classification, inasmuch as P could not exceed a certain maximum.

In Table 9 (pages 866–867) the foregoing formulae were applied by the writer, for comparison between a series of automobile motors to existing types of motors represented by letters, specifications of which had been given to him by the makers or the owners.

In the mean-pressure column, P, calculated from the formulae, some noticeable differences would be found. The figures 7·10 to 10·05, arrived at respectively for the motors E, C, N, O, P, were certainly exaggerated, and the error arose from the fact that either the motor did not develop the H.P. stated by the maker, or, in order to develop it, had to run at a higher speed than the maker stated. The difficulty in classification of motors from the data supplied by the maker arose therefore chiefly from the inaccuracy of some of these data. This difficulty would nearly always have to be faced in connection with competitions, until competitors were compelled by regulations to produce a test sheet of the motor, or to allow their motor to be tested under a given load.

To obtain an accurate Table, which would be really reliable for purposes of comparison, on the plan of the Table which he had compiled, it would be necessary to test, either by brake or by means of a dynamo, the effective power which the motors, under examination, were capable of developing, and to count the number of revolutions corresponding to such power. The calculation would then give the real amount of mean pressure on the piston during one complete cycle, which pressure depended on—

1. The nature of the fuel used.
2. The richness of the explosive mixture.
3. The amount of compression.
4. The manner in which the motor was governed.
5. Negative resistances due to the section of valves inlet and exhaust pipes.
6. The ratio of the area of the piston and its stroke.

(M. R. Mathot.)

TABLE 9 (*continued on opposite page*).

	Serial Nos. and Marks.		Cylinders. K.	Revs. per Min. N.	Effective Power. F.	Revolutions per H.P. $n: \frac{KF}{N}$.	Piston.		
	No.	Mark.					Stroke. C.	Diameter. D.	Area. S.
			No.	No.		No.	m.	cm.	cm².
I n: 90 to 140	1	N	1	1200	9	133	0·110	10·6	88·25
	2	M	1	900	9	100	0·190	11	95·03
	3	F	1	900	9	100	0·145	14	153·94
II n: 140 to 190	1	O	1	950	5	190	0·100	9	63·62
	2	P	2	900	12	150	0·110	9	63·62
	3	H	2	850	9	188	0·130	9·6	72·38
	4	A	2	900	10	180	0·130	10	78·54
	5	S	2	750	9	167	0·150	10	78·54
III n: 190 to 240	1	B	2	900	8	225	0·132	9·2	66·48
	2	L	1	1000	5	200	0·110	10·5	86·59
	3	G	2	800	8	200	0·125	10	78·54
	4	D	2	900	9	200	0·132	10	78·54
	5	Y	2	800	8	200	0·160	10	78·54
IV n: 240 to 340	1	C	1	1300	4·5	288	0·100	8	50·26
	2	E	1	1500	6	250	0·100	9	63·62
	3	R	2	750	6	250	0·095	9·5	70·88
	4	U	2	1000	8	250	0·110	10	78·54
	5	V	2	900	6	300	0·110	10	78·54
V n: 340 to 440	1	T	2	1600	8	400	0·090	8	50·26

(*concluded from opposite page*) TABLE 9.

Product. $S \times C$.	Modulus of Power. $a : \frac{S \times C}{11250.}$	$\frac{1}{a}$	Mean Pressure. P. Kg. per cm^2.		
9·707	0·000862	1160	8·70	(b)	I n: 90 to 140
18·056	0·001605	623	6·23		
22·321	0·001984	504	5·04		
6·362	0·000565	1770	9·3	(b)	II n: 140 to 190
6·998	0·000621	1610	10·70	(b)	
9·409	0·000836	1200	6·35		
10·210	0·000907	1100	6·11		
11·781	0·001047	957	5·20		
8·775	0·000780	1280	5·20		III n: 190 to 240
9·525	0·000846	1180	5·90		
9·818	0·000872	1150	5·75		
10·367	0·000921	1090	5·45		
12·560	0·001116	896	4·50		
5·026	0·000446	2240	7·75	(b)	IV n: 240 to 340
6·362	0·000565	1770	7·10	(b)	
6·734	0·000598	1670	6·65		
8·639	0·000768	1300	5·20		
8·639	0·000768	1300	4·32		
4·523	0·000402	2490	6·20		V n: 340 to 440

(M. R. Mathot.)

It would thus be sufficient to measure this mean pressure on diagrams obtained by means of the Mathot indicator. It would be still better to check the accuracy of the results obtained by brake tests, by means of the diagrams obtained from the indicator. As M. Forest said, the publication of test results obtained from motors in connection with races would supply makers with useful data for purposes of comparison, and would certainly lead them to realise improvements in the design of their motors. Moreover, during the brake tests of a motor it would be well to keep an account of the petrol consumption per Eff.-H.P. per hour, and to state the figure obtained in the published tables.

The publication of such information within a certain period would lead to the discovery of the hitherto unknown law, which actually governed the relation between the various data to be considered, namely, power, speed, fuel consumption, etc., and to determine the amount of correction to be applied in each case.

Mr. Edwin L. Orde wrote that the author had referred to a statement which the writer had made on the effect of the presence of water in liquid fuel (page 744), and had compared it with one made by Mr. R. G. Paddock in a Paper read before the Technical Society of the Pacific Coast. On reading Mr. Paddock's Paper again, the writer could not see that anything was advanced on this point with which he could not agree.

In treating the question of the application of liquid fuel to the welding of iron, he found that if saturated steam was used for spraying the oil, the temperature of the flame was too low, and it was therefore necessary to use superheated steam. But as he understood the Paper, he gathered that Mr. Paddock did not suggest that the higher temperature was due to the presence of moisture, but to the increased rapidity of combustion which was gained by the use of superheated steam. Captain Longridge's experience as to the effect of moisture, when present in the charge of petrol or alcohol vapour, was most interesting, and he himself hoped that some satisfactory explanation of the phenomena might be forthcoming.

It would be interesting to know whether the petrol was introduced into the cylinder through a carburettor, or in the form of spray, and if the water was injected into the cylinder independently of the charge, or in conjunction with it. Any gain there might be in efficiency would, he thought, be due rather to the reduced loss of heat through the cylinder walls from the cooling effect of the water, and possibly an increase in mean pressure, than to any improvement in combustion; though in the absence of any information as to the composition and temperature of the waste gases, it was impossible to do more than conjecture. It seemed a pity that no arrangements had been made to obtain such data, as they were indispensable in investigating such questions as these, and the apparatus required was by no means costly or complicated. As far as the writer's experience with liquid fuel went, the effect produced on the flame by the presence of moisture was wholly bad.

In regard to the question of the comparative efficiencies of spirit-motors, petroleum-motors, and steam-engines, the author quoted an article upon Spirit Motors in France (page 692), in which the efficiency of the petroleum engine was given as 15 per cent. as compared with 23 per cent. for spirit-motors and 13 per cent. for steam-engines. Exhaustive trials upon the Diesel oil-engine, which had been carried out by Professor Meyer in 1901, gave as a result an efficiency of 30·1 per cent. under normal brake load, so that the efficiency of the alcohol engine did not appear to compare quite so favourably as the author represented.

Mr. William Sisson wrote that he thought the remark (page 670) respecting assimilation of the car-motor to the steam-engine in regard to flexibility was a very cogent one. The steam-motor, in spite of the great disadvantage of the boiler, had an enormous advantage over the inflexible internal-combustion motor on the grounds named, and not only on these grounds, but also because of its great relative capacity for a heavy overload, far in excess of the normal full load; and at the same time this capacity was obtainable without rendering the performance at normal full down to about half load uneconomical. This property was manifested every day in the working of electric power and traction plants.

(Mr. William Sisson.)

With regard to the material for the cylinders, the writer's experience of a good many years now in the use of a nickel cast-iron alloy for piston-rings, piston-valves, and their liners, in his high-speed engines has been most favourable. These castings were made from the crucible, and were far superior in closeness of grain and readily adjustable hardness to ordinary cast-iron of the very best brands obtainable. He felt certain that the working surface secured with this alloy was far superior to that which would be obtained by a tube of steel of the highest carbon, which would be workable in drawing.

The faulty arrangement of valves in their chests (page 681) was responsible for a great deal of difficulty in valve working, and his experience fully enabled him to support the author's opinion thoroughly, as it was a point to which he had always attached great importance. The higher the number of reciprocations, the more important it was to ensure that the delivery round about the valve, when it was lifted, was symmetrical; indeed, when room permitted, it was even expedient to contract the chest slightly above the top of the valve before the level of the discharge pipe was reached.

The formulae (page 685) gave a velocity to the gases, so far as he had examined them, of about 6,400 feet per minute, calculated in the conventional method by taking mean piston-speed and full valve area, assuming as an average that the width of the seat was $\frac{1}{8}$th of the outside diameter, which made the net diameter of the valve three-fourths of that upon which the area per formula was based, according to the explanation at the foot of the page, and thus the effecting area was not more than $\frac{9}{16}$ths of that given by the formula. If then there was no error in the statement, the lift given was unnecessarily high, for, of course, a lift of $\frac{1}{4}$th of the outer diameter gave the full area of a circle of that outer diameter. It might also be mentioned, of course, that the annular or double-beat valve Fig. 6 (page 684) would have no advantage at all, if the proportions of lift in the formulae were adopted; in fact, the real advantage of the multiple seat valve was to enable reduced lifts with the same delivery to be secured.

Regarding material for crank-shafts (page 721), the writer was solidly in accord with the author's judgment on this matter, and for about ten or twelve years he had used high carbon steel up to even 50 tons tensile, first for high-speed launch machinery, and later for his high-speed engines, where 45-50-ton "gun" quality steel was used. The forgings were made by the best Sheffield makers, and from the beginning he had never had any accident, or any reason to be other than amply satisfied by adopting this high-carbon steel; in fact, it was not only on account of strength and stiffness, but also the excellent working surface on pins and journals, which was thereby obtained. Of course, the material was expensive, and the machining was extra costly. He held so strongly the opinion in favour of this high-carbon steel, that he would not think for a moment of adopting the mild steel so generally specified about 30 tons tensile. It might be mentioned that in the case of a 360-I.H.P. Sisson Engine driving a large fan, the neck of the engine shaft was 6 inches in diameter just on the engine side of the coupling, while the shaft to which it was coupled on the other side of the fly-wheel was $6\frac{1}{2}$ inches. This latter shaft had fractured at least twice, if not three times, the material being mild Siemens steel, and apparently sound and good in quality, while the engine-shaft was absolutely unaffected, showing the great strength and reliability of the material.

Finding oneself so much in accord with the author's judgment on mechanical points generally, it was with some little delicacy that he referred to the artifice illustrated in Fig. 14 (page 711), but with deference he would submit that this could only be considered of interest geometrically, and when, if ever, materialized, it would be found most unsatisfactory, and really impracticable. In thanking the author for his very interesting and instructive Paper, he felt sure that he was only expressing the gratitude of many steam engineers, who wished to acquaint themselves with the interesting development of internal-combustion engines applied to motor vehicles, but who had neither the time nor the opportunity of following up the matter themselves, so that Captain Longridge's clear and apparently complete summary of the present state of development was very welcome, and much appreciated by them.

Mr. Henry Sturmey wrote that, whilst they might not agree with all of the author's theories and deductions, the Paper as a whole was most valuable, and was well calculated not only to inform but to induce thought on many points which might otherwise be overlooked. He was not altogether inclined to support the statement as to the ultimate triumph of the impulse-every-revolution engine. The difficulties in the way of making such an engine as really simple, as efficient, and as economical as the four-cycle type were so great that, although the possibility existed of overcoming them, the probability was remote. On the other hand he entirely concurred in the view that "the aim of manufacturers is obviously towards elimination of change-speed gear by increasing the flexibility and elasticity of the motor," and was convinced that the ultimate design would be found at the end of this line of thought, for the results already obtainable were such as to give—short of starting from a standstill—almost as great a flexibility of control as with a steam-engine, the Duryea engine for example working with a range of from 75 to 1,500 revolutions per minute.

He could not support the author in his advocacy of governing on the exhaust, for he could not bring himself to think that the right place for *all* the products of combustion was anywhere else than outside the engine, and he contended that the best results from every point of view were to be obtained by the most thorough clearing out of the waste gases, and the working with the purest charge possible, a contention which was thoroughly borne out by the results obtained with the Dawson engine—a system which the author had overlooked —in which not only was the exhaust cleansed by a blast of air from a force-pump, but air at compression was added by the same means to the charge before compression, with the result of an added increase of from $33\frac{1}{3}$ to 50 per cent., over the power of the same engine worked without the air augmentation.

With regard to volume throttling, which the author condemned as "theoretically bad—" mainly, he gathered, on the score of fuel economy—he thought that both the author and engineers generally placed altogether too high a value upon this question of fuel economy. What he meant was this: whilst with stationary engines

running in workshops, the conditions being largely constant, all the engine had to do was to run regularly at one rate of speed—and this any modern gas-engine might be depended upon to do—so that there was very little left for experiment, except the question of fuel cost. With the automobile engine, however, the conditions were entirely different. It had to do, and was expected to do, practically "everything but talk—" and it would do *that* to the man who knew his motor—and if a method of control, which might not be theoretically the most economical, would give better results in other ways, it was to be preferred. After all, fuel cost was the smallest of an automobilist's expenses, and he questioned whether the difference between the working of the most theoretically perfect fuel consumer and one which was "theoretically bad" would make £1 difference at the end of the year to the average user, and that was a sum hardly worth considering, at any rate in the present "state of the art." Moreover, it was a striking commentary upon the author's sweeping condemnation of throttle control that (although Duryea, the Wolseley, and one or two others had been using it for years) it had, during the past twelve months, received an enormous increase of favour, so much so that it bid fair to become universal. Although most of those who had recently adopted it had not discarded, but still retained their spark advance gear, this latter in practice was hardly ever used, the throttle only being relied upon for regulation. Nor could that control by varying the point of ignition, which had hitherto been almost universally employed, and which apparently received the author's approval—as it certainly did not receive his condemnation—be any more economical than the system he so sweepingly decried, for, with spark variation, whilst the full charge of mixture was drawn in, its full value as a power producer was only obtained when firing point and engine speed were in exact proper relation to each other. Although this method was useful and economical when spark variation was used to get the best results, yet when, owing to gradient, the engine speed varied, and when it was used for the purpose of varying the engine speed irrespective of gradient, as had generally been the case, then it was probably the most wasteful and inefficient system of any.

Mr. A. Suggate wrote that the author mentioned (page 741), experiencing the trouble of pre-ignition supposed to be consequent upon the flashing of the cylinder lubricating oil, and in this connection the writer would give his experience of getting over the same trouble in another class of engine. Some years since he had carried out a few experiments with caloric or hot-air engines, and had been much troubled by the inefficient lubrication of the cylinder, consequent upon the flashings of the oils used. Now a caloric engine was quite unlike a motor-engine, besides having its piston speed and initial working pressure very much less; but in the matter of high temperature of the working fluid, they were both alike, and, if there was any difference, he thought the caloric engine was the hotter of the two, for it had not the advantage of a water-cooling jacket that the motor engine had.

He soon found that no satisfactory test results were to be obtained, unless a better means of lubrication could be devised, and with that object in view he examined samples of graphite, more commonly known as plumbago, from home and foreign markets. Having made a selection, and having mixed with the graphite two or three other ingredients, a few rings were made; one of the rings was fixed on the face plate of a lathe, turned, bored, faced, and cut off exactly in the same way as cast-iron packing-rings were made for steam pistons. This graphite ring was then cut into four equal segments, and the segments mounted in prepared recesses in a cast-iron ring of less diameter than the cylinder, so that the segments projected about $\frac{3}{32}$-inch beyond the side of the ring.

The ring was expanded by springs and secured in its place upon the piston by the junk-ring or head of the latter. With this solid lubricant the engine ran successfully for some four or five days, averaging 6 hours per day; the graphite ring was then examined and found to be but little worn, barely $\frac{1}{16}$ of an inch. He found that there was one thing that must be attended to, in order to make this solid lubricant a success, namely, that the packing rings must not be too tight, otherwise they would scrape the lubricant off the cylinder sides. He thought this was a common fault with most motor-engines, but perhaps this extra tightness of motor-engine packing-rings had

been found necessary, in consequence of the unequal expansion of the cylinder, due to the casting of the head and cylinder in one.

To take an illustration showing how much pressure approximately a packing-ring should exert against the cylinder sides, let them assume the piston to make the out stroke in one second, let them also assume the packing-rings only to fit so tight as to let the working fluid when formed or let in the cylinder take one second to leak through or pass the rings; then when the piston got to the end of its stroke, the working fluid was just beginning to leak through or pass the piston, but this did not matter, as the exhaust should now be well opened. It was certain that if the packing-rings were much tighter than this, it meant increasing by a good percentage the difference between the brake and indicated horse-power, for no apparent reason. It might be convenient to term this particular fit of the packing-rings their time-tightness or time-fit, thus the faster the speed of the engine the less was their required time-tightness, and if the stroke of the piston was made in $\frac{1}{5}$ or $\frac{1}{10}$ of a second the time-tightness of the rings required to be approximately $\frac{1}{5}$ or $\frac{1}{10}$ of a second. If Captain Longridge could introduce successfully solid lubricating rings, he would get over all difficulty from pre-ignition in the cylinder of motor-engines.

Mr. W. Scott Taggart wrote that the subject of lubrication was one that occupied its due share of the Paper. Owing to the attitude of the author, it had been dealt with in such a manner as to leave the subject a purely open one, so that the remarks scarcely lent themselves to be criticised. One might therefore enlarge on the points mentioned with the idea of showing that the questions of flash-point and viscosity were usually considered from an entirely wrong point of view. It might be pointed out that the suggestions on page 736 "that warm though not hot bearings, therefore, appear to be advantageous" was not quite the correct deduction to make, otherwise it might appear that the temperature of 82° C. mentioned, with its low co-efficient of friction, was the result of friction. Now 82° C. (180° F.) was certainly hot for a bearing, and considerable friction must exist to produce this temperature, therefore a good deal

(Mr. W. Scott Taggart.)

of power was being wasted. If a bearing was raised to 82° C. from some external source of heat, then the co-efficient of friction was decreased, but friction itself must not be the source of the heat.

The question of premature so-called automatic firing of the petrol mixture or gas mixture was one that had, at various times, received a good deal of attention, and was of considerable importance. One hears the words "flash-point" of oil frequently mentioned, but few gave much thought to it. The flash point to be taken was the closed test from the nature of the case, but the closed test was one made under the usual atmospheric pressure. If an oil had a closed-test flash-point of say 550° F., its flash-point under 75 lbs. pressure would be considerably higher; in other words, it would require to be raised to a higher temperature when under pressure, before it would give off inflammable vapour. Now, owing to the high temperature of the explosion, there existed no lubricating oil that could withstand such a temperature without disintegration and forming an explosive mixture, and if oil was anywhere near in sufficient quantities such a mixture was obtained. The object was to so apply the lubricant that it could only exist as a thin film on the wall of the cylinder, and this oil to have as high a flash-point as possible, the flash-point, however, must be found under the same pressure as the compression pressure; if a good oil were used, a slow feed was all that was necessary to keep the film intact. Such a film as mentioned would be almost prevented from vaporising, and so forming an inflammable mixture, partly because the wall of the cylinder would keep it cool, and partly because the interval of time during which the explosion lasted was too short to produce the vapour. The conclusion of this reasoning was, that the lubrication of a motor-cylinder must not be done on the spray method, nor admitted to the end of the cylinder where the explosion took place. As little oil as possible must be used, so that it did not accumulate in this end of the cylinder.

In regard to oil vaporising, it was common knowledge to those accustomed to make flash-point tests that visible vapour came off the oil at a considerably lower temperature than the flash-point, but this vapour did not appear to be inflammable, and it also did not interfere

with the lubricating qualities of the oil. Poor oils lost large percentages of their weight at a rapid rate at much lower temperatures than their flash-points, and as such oils were poor lubricants, even large quantities have little effect in reducing friction. Speaking generally, oils might be said to have three critical temperatures, namely, vaporising temperature, flash - point temperature, and distillation temperature. The burning point might be added, if this was considered apart from the flash-point. The following was an illustration of an oil that worked remarkably well on an oil-motor without leaving a carbon deposit: vaporising temperature 194° F., flash-point 400° F., burning point 468° F., and distillation point 602° F. The vapour that came off between 194° F. and 400° F. was not inflammable and it did not yield a distillate. It had to be raised to 602° F. before a distillate was formed.

The author remarked (page 740) on the formation of carbon deposits being probably due to the gas fuel; the writer would say that that was true to a certain extent, but the poor lubricants frequently used, resulting in carbon deposits in larger proportions than deposits due to gas could be easily proved. The carbon resulting from the oil fuel was always in the form of a very thin film of soft soot, whilst burnt lubricating oil was hard granular carbon sometimes dry and sometimes oily or gummy. All that was necessary was to take an engine and use a variety of oils on it, and note the difference in the amount of carbon deposited. Some oils would be found to deposit more than others. Results obtained in this way also pointed to the fact that the flash-point of the oil had little influence on the burning up of the lubricating-oil in the cylinder. A high flash-point oil sometimes resulted in more carbon deposit than a lower flash-point oil. In regard to the remarks on the last paragraph on page 741, the writer thought that the spraying of an oil in a gas-, oil-, or petrol-engine was not a suitable method of lubricating a cylinder; it was not even good for a steam-engine using superheated steam. The only method was to get the oil on the cylinder walls without allowing it to mix with the petrol charge. A vertical engine, if the lubricant was not sprayed or allowed to get into the end of the cylinder, would never experience premature firing,

(Mr. W. Scott Taggart.)
even with a low flash-point oil. The question of high flash-point oils being very thick at normal temperature was undoubtedly a difficulty; there was no difficulty about making such an oil, but most of the advantages of a lubricant were lost in obtaining it, as it was likely to develop or deposit tar at a high temperature, and its lubricating properties disappear. A good oil that was limpid in winter and had a high flash-point could be easily obtained, and the writer's firm (Henry Wells Oil Co.) had not heard of premature ignition occurring on engines using their motor oils.

A number of oil users, and even manufacturers, had incorrect ideas about viscosity. The influence of heat lowered the difference between thick and thin oils to an enormous extent; for instance, let them take oils, one much thicker than others at a normal temperature of say 70° F., now let them raise the temperature of each, and as the temperature increased, it would be noted that difference in viscosity decreased until at the temperature of 400° F. there was practically no difference between them. The writer could extend the list of temperatures given below, but even at 400° F. the viscosities were sufficiently close to prove the point. All oils, whether thick or thin at normal temperatures, when put into a hot cylinder of any motor, ceased to be distinguishable from each other so far as viscosity was concerned. The following were examples of four oils, A B C and D, showing variations in viscosity at various temperatures:—

TABLE 10.

Temperatures.	70° F.	212° F.	250° F.	300° F.	350° F.	400° F.
Viscosities A	817·0	53·0	46·0	40·0	34·0	32·0
„ B	1189·0	53·0	43·0	35·0	31·0	30·0
„ C	453·0	82·0	51·0	34·0	31·0	28·0
„ D	3010·0	79·0	50·0	36·0	33·0	31·0

Mr. Hector M. Walker wrote that the author raised certain points on the vital subject of lubrication, which were worthy of the earnest consideration of all engineers. It would tend to economy to use a

high-class hydro-carbon grease, instead of oil, for change-speed gears, as loss from leakage would be practically done away with. He questioned if it were possible to fire a high-class hydrocarbon lubricant, such as "Wilburine" at 624° F. (maximum figures quoted by the author) or even at a temperature far beyond this. His reason for saying so was, that they took this oil in a test to 867° F., and there was no sign of fire or explosion during the accessions of the various temperatures up to this point. Professor Ripper in his experiments with superheated steam had taken "Valvoline" (a grade lower than "Wilburine") to 760° F with perfect satisfaction.

The author quoted Messrs. De Dion and Bouton as having invented a self-igniter, in which a piston compressed a little of the petrol mixture, and the ignition striking back fired the charge. Could they not look in this direction for a probable cause of premature ignition? Let them suppose that a miss-fire occurred, an augmented charge might be in the cylinder for the next explosion, and Messrs. De Dion's principle of ignition, by compression, be given effect to, in a premature manner. Regarding the author's experiment with petrol in a tin case at partial red heat, the failure to obtain ignition at this temperature seemed strange, unless the mixture was "too poor." The successful ignition of the lubricating oil, under similar test conditions, might be accounted for by saying that there was a richer mixture, and consequently more carbon which was deposited on the hot surface (as the oil vaporised), and becoming incandescent, fired the charge. Was carbon in this dry state more potent as an igniter than metal at a partial red heat? Of course a partial red heat was away beyond the fire test (460° F) of the oil experimented with, which he assumed—from its fire test—was a low grade oil; such an oil under certain conditions could become a source of trouble, if not actually dangerous. In internal-combustion engines, with an excess of such an oil in the cylinders, it seemed very probable that a portion of the petrol might be absorbed and held (more so when a miss-fire occurred) in saturation by the lubricant; an augmented charge of petrol was now in the cylinder, and might go off prematurely when the temperature favoured ignition before full compression was reached.

(Mr. Hector M. Walker.)

Looking at the question from another point of view, namely, deficient lubrication: this favoured a dry deposit of carbon (from the petrol). Now the liability of fine dust to fire easily is well known. Some might remember the explosion which wrecked the Kingston Flour Mills in Glasgow a number of years ago; the explosion and fires which occurred frequently in coal mines; and even the simple experiment of dropping iron filings on to a flame, all tended to show how easily fine dust ignited and became incandescent. Suppose there was a deposit of dry carbon on the cylinder wall, it would be easily rendered incandescent by the sliding friction of the piston, thus supplying the flame to ignite the charge prematurely. Incandescence need not be continuous.

He was entirely with the author in thinking that low-flash lubricants contained the elements favourable to cause premature ignition, but he did not hold with him in demanding the highest obtainable flash-point in lubricating oils. In this connection there were two flash points to consider, namely, the highest possible and the highest practicable. To make his meaning plain, he would look at this question from the oil-makers' point of view. To make a hydro-carbon lubricant of the highest grade, the still is filled with a special crude stock, and a fraction containing the light hydro-carbons was distilled over, until a certain point was reached. This he would call the "critical point." If quality of lubricant was the all-important consideration, distillation was now stopped, and in the manufacture of the "Valvoline" oils, this residue was repeatedly filtered through animal charcoal to remove all impurities and solid matter, which the crude oil might have contained. They accepted the flash-point that came in conjunction with other important physical conditions necessary to the production of a good lubricant. If they were looking for flash-point alone, they could drive the distillation further than what he had called the "critical point," and, if he might be allowed the expression, exceed the elastic limit of the material, damaging the original structure of the oil by burning it and causing the formation of tarry matter in the product, thus impairing its lubricating qualities. The following example would serve to illustrate the value of flash-point considered alone. His firm made

these two oils, namely, "Wilburine" cylinder oil by distillation with superheated steam and the filtration process already described, the other a common unfiltered cylinder oil:—

"Wilburine."	Common Black Cylinder.
Open Flash 535° F.	Open Flash 580° F.
Specific Gravity 0·900.	Specific Gravity 0·909.
Fire Test 610° F.	Fire Test 665° F.

Relative cost to the consumer—

"Wilburine" 60. Common Cylinder Oil 21.

He hoped he had made it quite clear that the highest obtainable flash-point was not the sole, or most important measure of value of lubricating properties of an oil.

Regarding the method of "feeding" an oil such as "Wilburine," he suggested that it should be fed through the side of the cylinder, against the piston, below the first packing-ring (top ring) when the piston was at the end of the working stroke, and a small groove turned in piston opposite the oil inlet; it would thus be applied exactly where it was required, and be diffused over the cylinder wall in a film by the moving piston. This implied forced lubrication; the lubricator should be so arranged that it could not drain itself into the cylinder during a stoppage. If adequate means were taken to insure that a high-class hydro-carbon oil got to its work continuously, he was convinced that it would do better work than any mixed oil as at present used on gas- and oil-engines. The present practice of using a thin-bodied oil, that is free flowing oil, was necessitated by the conditions of feeding; the wire dipper picked up the oil and dropped it into the tube through which it had to flow by gravity to its work. Progression by flow implied a light bodied (low-flash) oil, which was stiffened up by a large addition of animal oil, to enable it to stick to the hot cylinder wall. This addition of animal oil, in time, caused gummy deposits on the working surface of piston and cylinder. Oil of this type had been followed by "Wilburine" on motors with great success and satisfaction to the users after the gummy deposits had been cleaned away, which took some time, according to the oil previously used. A word or two

(Mr. Hector M. Walker.)
might be said about the apparent dearness of a high-class oil. Method of manufacture regulated the selling price and lubricating value of the oil. Oil prepared by the sulphuric acid process could be produced at a fraction of the expense that a charcoal filtered oil cost. The price per gallon of the high-grade oil appeared high, but the efficiency per gallon was high. A correspondent writing to the "Autocar" (12 July 1902) said that his $3\frac{1}{2}$-H.P. car, with air-cooled engine, and no water-cooled head had run 2,000 miles on less than one gallon of "Wilburine." There were no bad effects, and the engine never overheated. A 3-H.P. "Benz" car ran 110 miles on a consumption of $1\frac{1}{2}$ oz. of "Wilburine" for cylinder lubrication.

Regarding the use of graphite for lubrication of cylinders of internal-combustion engines, it was used in the cylinders of the engines of a line of steamers from the Clyde to Bristol about twenty years ago. The superintendent engineer replaced cylinder oil with graphite and water. After a time cylinder trouble was reported on one of the steamers, with the result that the cylinder was badly scored. Some time after this another steamer of the same line reported cylinder trouble. On examination it was found that the cylinder metal had fused in a streak for the length of the stroke. The matter was investigated, and the conclusion arrived at was, that a dry streak had occurred by friction of piston on the graphite-packed (pores of metal filled) metal of cylinder wall. Incandescence resulted, and fusion of cylinder metal followed. The action of graphite in a cylinder was to fill clearance spaces, and in time to choke passages where it could accumulate.

Mr. J. Veitch Wilson wrote that in respect to lubrication, the Paper raised four questions:—(1) The origin of the carbonaceous deposits; (2) the body and flash point of lubricants for water-cooled cylinders; (3) the means of application; (4) the use of pure hydro-carbon oils, fatty oils, or compounds of these in oil-engines.

Some few years ago, having been interested in the origin of the carbon found in the cylinders of gas- and oil-engines, he applied for assistance to several of his friends who were kind enough to provide

him with data from actual work. As there was no room for detail here, he furnished the following grouped figures:—Three gas-engines each of different make and, of 6, 24 and 90 B.H.P. respectively running for one week each = 160 hours total, used together 98,738 cubic feet, say 3,300 lbs. by weight of gas. During the same time these three engines accounted for lubricating oil as under—

Quantity supplied	24·1 lbs.	= 0·73 per cent.
„ recovered	11·5 „	= 0·35 „ „
„ used (by difference) . . .	12·6 „	= 0·38 „ „

Two oil-engines, by the same maker gave the following results:—A new engine 25 B.H.P. in a week of 54 hours used 1,066 lbs. of petroleum, and during the same period accounted for lubricating oil:—

Quantity supplied	28·5 lbs.	= 2·67 per cent.
„ recovered	15·3 „	= 1·43 „ „
„ used (by difference) . . .	13·2 „	= 1·24 „ „

This engine being new took an extra quantity of lubricating oil as compared with the next, an older and smaller engine, namely:—An oil engine of 8½ B.H.P. which in a period of 66 hours' running consumed 449 lbs. of petroleum and of lubricating oil:—

Quantity supplied	4·37 lbs.	= 0·97 per cent.
„ recovered	1·37 „	= 0·31 „ „
„ used (by difference) . . .	3·00 „	= 0·66 „ „

The figures on the right side in each case showed the percentage of lubricating oil to gas or to oil used for fuel, and from these it would be seen that, in his communication to the author (page 740), he considerably overstated the proportion of lubricating oil (which he unfortunately gave from memory) used in relation to fuel. These figures however still more accentuated his contention that, as coal-gas and petroleum used for fuel and oils ordinarily used for lubrication of gas- and oil-engines had approximately the same formula (carbon 84, hydrogen 16), it was reasonable to assume that the bulk of the carbonaceous deposits found in cylinders, or combustion chambers, valves, and silencing boxes, was due mainly to that material of which

(Mr. J. Veitch Wilson.)
the larger quantity was used. He did not, however, wish it to be supposed that he entirely repudiated all responsibility on the part of lubricating oils, as it was well known that the tendency to produce carbonaceous, and even gumming deposits was much higher in some mineral oils than in others, and that the quantity and nature of the desposits in gas- and in oil-engines must to some extent be affected by the quality of the lubricant.

In reference to the body and flashing point of oils for water-cooled cylinders, he would suggest that engineers had all been rather prone to treat them as they would treat air-cooled cylinders, or at any rate as if the crucial temperature to be provided for had been that of the explosion itself, rather than that of the walls of the cylinder. As a matter of fact he took it that the conditions of a water-jacketed gas- or oil-engine were much less severe than those which they regarded with equanimity in a modern steam-engine. In the latter, every effort was made to maintain the highest possible temperature, and in an engine working at 160 to 180 lbs. pressure with live steam in the jacket, the walls of the cylinder must attain a temperature 360° to 370° F., whereas it seemed to be commonly accepted that the temperature of the walls of the water-jacketed internal-combustion cylinder might vary from 220° to 250° F. In the larger cars with large wheel base, good springs and ample water-cooling arrangements, the working conditions were probably not much more severe than in stationary engines, and there was no reason why the former should not be satisfactorily lubricated with the oils of the same class as were adopted for the latter, but in smaller cars, with restricted cooling arrangements and greater vibration, oils of greater body were required.

In respect to systems of applying lubricants, he took it that little better or more efficient systems could be desired than lubrication by splash from the crank-chamber in the case of vertical engines, and by the gas-engine method by dropping oil through the side of the cylinder on to the piston in the case of horizontal engines. The trouble came up in connection with the distribution of the oil, and mainly, he believed, through the inadequacy of the bore of the pipes. The choice of actual lubricators was ample and good, including as it

did Drake's working by air pressure, Hamelle's and Dubrulle's separate apparatus working by positive pumps driven by the engine, and various systems dependent wholly upon gravitation, but unless care was taken to provide a lubricator adapted to the oil required by the car, or conversely to select oil which would flow through the lubricator, the results might be disastrous.

The last point referred to by the author in regard to lubricants was that of pure hydro-carbons *v.* compounds of pure hydro-carbons and fatty oils. Since Captain Longridge quoted such a high authority as Messrs. Crossley in favour of the use of fatty oils, he presumed as ingredients in lubricating oils for oil-engines, one hesitated to express a contrary opinion, although on the other hand it appeared to be the opinion of scientific experts, including Mr. Boverton Redwood, that fatty oils ought to be wholly excluded from use in internal-combustion engines of all kinds. He hesitated at present to express an opinion regarding the use of compound oils in oil-engines, although practice had certainly shown that oils of this description might be and were used with most satisfactory results in gas- and petroleum-engines. He hoped, however, to have an opportunity of making practical trials, with a view to obtaining further information regarding this matter, and he would no doubt be able to publish the results when these had been obtained. In conclusion it might, however, be worth while to remind the members that, as fatty oils contained the elements of fatty acids, which required for their formation the addition of oxygen, the necessary conditions appeared to be provided in internal-combustion engines by the formation of water as one of the products of combustion, one gallon of water being formed for every gallon of spirit or oil consumed.

Mr. Charles Wood wrote that there were, to his mind, some very great improvements necessary to place oil-cars on a commercial footing. The car should be such as not to require an expert man to drive and keep it in repair, but so that any man of ordinary intelligence could take charge of it. A great amount of trouble might be avoided by discarding the multi-speed gearing, and making the engine speed variable at the will of the driver, so that he could

(Mr. Charles Wood.)

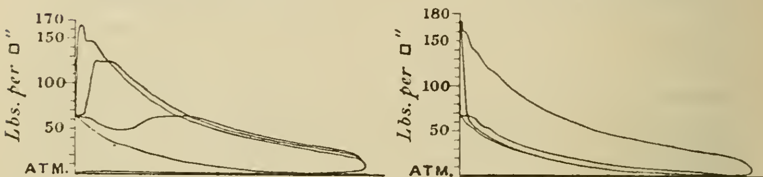
fix it easily at any speed from 300 to 900 revolutions per minute, and geared so that the 900 revolutions per minute would give twelve miles per hour. This would also do away with much of the offensive rattle of the car, and would make it at once simple and efficient in its performance.

One speaker mentioned the trouble that he had experienced with exhaust valves, when the speed of the engine reached 1,000 revolutions. The writer did not think he could expect any other result from such a speed, and would draw his attention to the following figures, namely:—1,000 revolutions = 2,000 strokes per minute, which gave 33 strokes per second. This did not give very much time to fire and expand the light charges that would occur when the engine was

Oil Engine (*Craven*) 250 *revolutions per minute.*

Fig. 41. Without water injection.

Fig. 42. With water injection.



firing every cycle. To enable him to discharge the burnt gases rapidly, he used a valve of large diameter that must be lifted against the pressure of the exhaust. At such a high speed the charge would only be partially burnt at the end of the stroke. He was therefore opening the exhaust-valve probably against a pressure of 70 or 80 lbs. per square inch, and instead of burnt gases passing the exhaust valve he would get the flame of the explosion.

With regard to the injection of water with the charge, he showed two diagrams, Figs. 41 and 42, taken from a stationary oil-engine using common paraffin. It had a $4\frac{1}{2}$-inch piston and 7-inch stroke at 250 revolutions per minute. He built it seven months ago, and it had been in constant use ever since. Fig. 42, with the water, was certainly the better, and a similar one worked out at 48 lbs. per square

inch mean-pressure. A diagram similar to Fig. 41 worked out at 42·8 lbs. per square inch. Fig. 41 showed early firing at each explosion, while Fig. 42 fired at the exact point. When an excessive quantity of water was used, the engine fired late; as the water was increased, the engine fired later. He accounted for the two heavy shots on Fig. 42 through the apparatus for injecting the water being a temporary drip arrangement that probably did not keep time with the oil pump. He did not think early firing was caused by the vaporisation of the lubricating oil, unless it was caused by the carbon deposits forming small projections on the combustion-chamber walls, that remained in a state of incandescence. Referring to the engine recently designed by the author of the Paper, the writer did not think it would revolutionize the motor-car industry. It would cause very rapid heating of the cooling water, a notable weak point in all engines of the two-stroke type.

Captain Longridge, in giving his written reply to the speakers and correspondents, wrote that he would follow the subject-order of the Paper:—

Horizontal Motors.—He would not waste time over such continental engineers as, Mr. Sennett stated, attributed difficult lubrication and uneven cylinder wear to the horizontal motor. The objections were popular fallacies.

Certain other Motors.—As regards his (the author's) two-cycle motor, Mr. New (page 791) was in error. The scheme would not be equally applicable to a four-stroke engine. To use the front of one cylinder to pump air into the combustion chamber of the other cylinder would only involve waste work, unless the air so pumped was carburetted and fired, when the engine at once became two-cycle. He was also mistaken in supposing the engine had a reduced charge. The amount of air drawn into the front of the cylinder by the more complete vacuum in his engine was really greater than that sucked into a similar-sized Otto cylinder, because in the latter the presence of the exhaust rendered the vacuum very imperfect. Again, in the ordinary Otto motor, air and petrol vapour together were drawn in, but, in his motor, air alone was taken, consequently in a larger amount,

(Captain Longridge.)
and, as this was completely pumped into the combustion chamber, the charge was heavier in his than in the Otto motor, even allowing a deduction for the piston-rod.

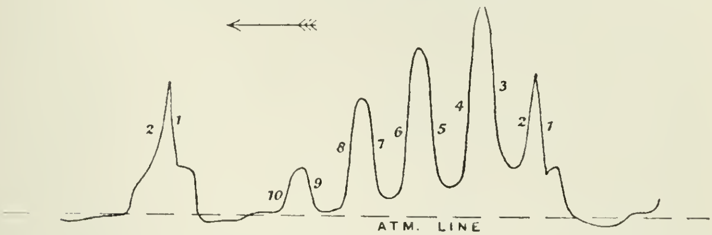
Mr. Sennett (page 795) and Mr. Hemingway (page 845) thought that the utility of his type of motor would be heavily discounted by the fact that the design made a very long engine; that a piston-rod and stuffing-box had to be employed, that the latter would probably heat and give trouble, and that the cross-head and guide would wear heavily, unless enclosed, etc. In reply he would say that his impulse-every-revolution twin-cylinder, 4-inch diameter by 6-inch stroke vertical motor, measured 27 inches from the centre of the crank-shaft to the highest point, which certainly was not a long engine. Longer motors were not objectionable, if the horizontal type were used. As the piston-rod ran always in cool air, he did not anticipate any heating trouble; it was very doubtful whether a stuffing-box would be needed, as a slight escape of air would be immaterial. The cross-head and guides were enclosed in the crank-chamber. Less adjustment was required than in the Otto cycle, because there was a constant thrust on the bearing. The total number of valves was less, because there was half the number of cylinders. The estimates given did not show that the motor would be expensive to build, nor was there any reason why the upkeep should be heavy.

Mr. R. Lucas (page 800) and Mr. Mervyn O'Gorman (page 811) had advocated methods of construction which were characteristic of the "Day" engine. On the score of simplicity, there was a good deal in favour of this type, but it was open to objections which were duly set forth in the usual text-books.

Residual Gases—Fuel Economy.—On the former point the speakers, he thought, had not appeared to appreciate the difference between gas- and petrol-engines. Gas-engine exhaust was usually inert, petrol-motor exhaust rarely, if ever so. This was due to the high speed of the motors, and the slow burning of petrol mixtures. The incomplete combustion could be recognised by long streaks of flame from the ports when the exhaust-pipes were removed. He had recently proved it by a Mathot indicator diagram from a Daimler

twin-cylinder motor, governed on the "hit and miss," in which the exhaust gases were retained in the cylinder. The typical curve so obtained was the following Fig. 43:—

Fig 43.
Mathot Indicator Diagram,
From a Twin-Cylinder Motor (Daimler).



It would be observed that the pressure immediately following the "cut-out" was much higher than the average pressure of explosion marked 1, showing that combustion continued during the course of period 3. The actual rates of combustion of petrol mixtures, under the conditions of engine work, did not appear to have been ascertained. In 1900, Mr. C. E. Oliver made some experiments with gasoline air mixtures, the gasoline having a specific gravity of 0·71, and a calorific value of 21,500 B.Th.U. The mixtures were first thoroughly diffused, transferred under the given pressure to the explosion cylinder, and then electrically fired. The results are tabulated as follows:—

TABLE 11.

Compression Gauge.	Ratio.		Time of Explosion.
	Gasoline.	Air.	
Lbs.			Second.
20	1	8	0·09
30	1	8	0·09
50	1	8	0 08
40	1	10	0·07
50	1	10	0·08
40	1	11	0·08
50	1	11	0·07

(Captain Longridge.)

In a motor at work, the initial temperature would be higher and combustion would proceed under expansion, both factors accelerating combustion; on the other hand, the diffusion would be less perfect, tending to produce slower burning than in the above tests. Whatever the real rates were, it was certain that the high speed of the petrol motor led to incomplete combustion. The residuum was still active, and that was one reason why its presence, under certain conditions, led to economy. It also assisted the rapidity and completeness of the charge combustion by the heat it contained and imparted. In his Paper on the "Pressure Indicator," Mr. J. E. Petavel stated:—"It is noteworthy that the change of curvature (increase of pressure at 0·05 second after ignition) occurs when the gas is at a mean temperature, about equal to that at which spontaneous ignition would take place. A similar result would, therefore, be obtained if we heated the gases, by the combustion of a certain portion of them, until the entire bulk was at the 'flash' point; the combustion would then take place simultaneously throughout the entire mass, resulting in an almost instantaneous rise to the maximum temperature and pressure." The secret of the perfect combustion of the Diesel engine lay in the pre-heating of the air to a temperature at which *all* the constituents of the explosive charge could simultaneously combine. The presence of hot exhaust-gases promoted pre-heating, and in this respect also tended to rapid and perfect combustion, and thus economy. Mr. Hemingway's view of the temperature question he considered quite wrong. In fact, he did not think that any of the speakers really sufficiently appreciated the slow combustion of oil and petrol mixtures, and the value of any method of accelerating it by raising the charge temperature within the cylinder. He would, therefore, like to refer them to Dr. A. Witz's account of Petreano's experiments in 1896, described in "Moteurs à Gaz et à Pétrole," 1899, Tome iii, pp. 144–5. "En élévant la température de ce dernier (l'air), on arrive à rendre explosif un mélange qui ne le serait pas dans les conditions ordinaires . . . on évite ces combustions lentes et prolongées . . . le travail augmente donc, et M. Petreano affirme avoir obtenu vingt-quatre chevaux par un moteur Otto qui en développait d'abord difficilement seize. Les encrassements du

cylindre disparaissent . . . Enfin le rendement du moteur est amélioré."

Were it not for arguments that had been advanced, it would be unnecessary to explain that no special virtue was claimed for exhaust gases as such; what virtue they had consisted in further combustibility and imparted heat. When, therefore, Professor Robinson (page 779) cited Mr. Oliver's experiments to show that lower explosion pressures were produced with residuum present than with a fresh pure mixture, he was rather beside the point. Mr. Oliver's residuum was obtained from a previous explosion protracted to complete combustion; it was, therefore, inert; and it was also used cold. It was, therefore, devoid of the two properties from which alone increased pressures could be expected. In 1896, in the discussion on Mr. Dugald Clerk's Paper,* Mr. G. Richard, of Paris, expressed his opinion that "the presence of the burnt gases did not impede the complete combustion of the active gas, and it appeared to diminish rather than augment the losses through the cylinder walls and the exhaust." At the same discussion, Dr. Witz, referring to the experiments, confirmed by Mr. Groves at this present meeting, remarked, "the success formerly obtained by Schrab, who recarburetted the burnt gases and introduced them again in the cycle, further confirmed this view." Quite recently, M. Mathot, an engineer with great experience of petrol motors, wrote to the author: "D'autres constructeurs estiment que la présence de gaz brûlés dans le mélange détonnant a pour conséquence de rendre celui-ci moins inflammable; à notre avis ceci n'est exact que si la proportion de gaz brûlés dépasse une certaine limite . . . "

In the author's opinion, the unqualified condemnation of the presence of exhaust gases in petrol motors, raised at this discussion, expressed a popular fallacy due to imperfect appreciation of facts. In running light, as in governing on the exhaust, the presence of exhaust, for the reasons given, undoubtedly conduced to economy or lower fuel consumption. Mr. J. Johnston (page 810) and Mr. H. Sturmey (page 873) considered economy in fuel to be a matter of indifference. This

* The Institution of Civil Engineers, Proceedings 1895–1896, vol. cxxiv., page 192.

(Captain Longridge.)

was a light-hearted statement that an engineer should be chary of making. In the great and widening application of the petrol engine to commercial purposes, the fuel bill would be a factor of importance. But it was not only a question of cost. By improving combustion so as to use the minimum fuel for a given power, there was less fouling of the cylinder and valves, lower exhaust temperature and reduced wear of the exhaust valve; in a word, cleaner and better running, requiring less attention and fewer renewals.

Piston Speed.—Mr. Roots (page 817) and Mr. New (page 790) suggested that he imagined a longer stroke gave greater expansion. He thought he had clearly expressed that the longer stroke admitted the use of a slower running motor, reduced piston speed, and more time for combustion—very necessary for oil and spirit fuels. He had enumerated (page 674) several reasons why very high piston speed was undesirable. He would now state the views of others who had studied the question. Dr. Slaby, experimenting with a small twin-cylinder Otto motor, found that if it were allowed to run continuously for some time, and the speed be increased, certain phenomena appeared which counter-balanced the favourable effect of the increased speed. These were chiefly manifested by rise in the temperature of the exhaust and increase of negative work. Dr. Witz also observed that, while the higher speed of the engine diminished the time during which wall action took place, this was counter-balanced by the more powerful action of the walls during that shorter time. Mr. Clerk, in 1896, stated "in small engines high piston-speeds are not practicable for many reasons." While Professor William Robinson, in his present work on "Gas and Oil Engines," remarked, "For an oil engine, the efficiency and power increase with the speed of piston, up to a certain limit . . . . and at higher speeds . . . . the efficiency and durability decrease, although the power may be increased."

It was not so easy to fix the exact speed limits, the main factor being the so far undetermined rates of combustion. Professor Robinson considered that for an oil engine (also for petrol motors), 600 to 700 feet per minute was the limit, above which efficiency suffered. In a recent communication to the author, M. Mathot

wrote :—" J'estime que la vitesse qui se concilie le mieux avec la vitesse de propagation de la flamme doit correspondre à 3 à 4 m. [9·9 to 13·2 feet] de vitesse linéaire moyenne de piston, s'exprimant comme suit, $b = \frac{Cn}{30}$, où C représente la course en mètres, et n le nombre de tours par minute. Jusqu'à présent il n'a, que je sache, pas été fait de sérieuses expériences sur la vitesse de propagation de la flamme dans les mélanges sous compression d'air carburé, comme jadis mon ami M. Dugald Clerk en a fait de mémorables sur les mélanges de gaz et d'hydrogène avec l'air, en vue des moteurs industriels. Néanmoins, la pratique, en ce qui concerne les moteurs d'automobiles, semble confirmer la théorie admise en matière de moteurs à gaz industriels, où il n'est pas d'usage de dépasser une vitesse linéaire de piston de 3 à 3·50 m. par seconde, ou 600 à 670 feet par minute."

Mr. G. Knap, in "Les Secrets de Fabrication des Moteurs à Essence," gave the following speed limits which it was not advantageous to exceed :—

TABLE 12.

Maximum Motor Speeds. (G. Knap.)

Motor Dimensions.				Revolutions per Minute.
Diameter.		Stroke.		
mm.	inches.	mm.	inches.	
62	2·44	70	2·75	1,400
66	2·59	73	2·87	1,800
72	2·83	80	3·15	1,700
80	3·15	120	4·72	900
80	3·15	110	4·33	1,000
85	3·35	150	5·90	750
85	3·35	125	4·92	800
90	3·54	155	6·10	700
90	3·54	130	5·12	750

(Captain Longridge.)

The adaptation of piston speed to the rate of combustion was insisted on by Mr. G. Moreau in his "Théorie des Moteurs à Gaz" (1902, page 150) in these terms: "Mais l'expérience est là pour nous apprendre que trop souvent les gaz sont mal brûlés, et nous croyons devoir insister sur ce point capital: *Proportionner la vitesse du piston à la nature du mélange employé.*" This advice was evidently endorsed by Mr. C. Wood (page 886).

Material.—Professor Turner would, he felt sure, be surprised that Mr. Hemingway could suppose the cylinder casting mixture given (page 676) resembled manganese steel. On this point, Professor Turner had written: "The difference between cast-iron and steel is that the former contains over 2 per cent. of carbon, as a general rule, and steel seldom has more than 1·5 per cent. of carbon. Steel contains practically no graphitic carbon, so manganese steels, which may contain more carbon than usual, are at once distinguished from my cast-iron by having no graphite, and all the carbon in the combined form. My mixture also contains more silicon and phosphorus than could be permitted in steel." No doubt good castings could be obtained with Mr. Hemingway's analysis (page 846), but not cheaply with British irons. The total carbon was too high and the phosphorus too low for our ordinary run of metal, and was more like what was obtained in America.

Valves.—Since the discussion, mechanically-operated valves had come so prominently into use that he would not further urge their merits. A controversy on the subject had been waged in the automobile press, and those interested might study the pros and cons in the "Motor Car Journal" (15 Nov. and 6 Dec. 1902), "Motor Cycling" (19 Nov., 1902), "Autocar" (29 Nov. and 6 Dec., 1902), "Automotor" (29 Nov., 1902), etc.

Carburettors and Carburetting.—He disagreed with Mr. J. Johnston's preference of the suction to the positive feed carburetter (page 860). Properly designed, the latter would act at high speeds. He also disagreed with Mr. Johnston's and Mr. Hemingway's advocacy of carburetting the charge, as it was inhaled. He was convinced of the superior advantage, for rapid and perfect combustion, of igniting the charge at as nearly as possible a

temperature at which *all* the charge constituents would combine. With the usual system of drawing in a carburetted charge, the risk of premature ignition rendered this impossible. The better plan, therefore, was to fill the cylinder with air only, pre-heat this by compression and by surface contact, and then inject the fuel. Surely the superiority of this method was established by the Diesel engine. By surface contact was meant contact with a hot, unjacketed combustion chamber. The separation, as far as temperature was concerned, of the combustion chamber from the working portions of the cylinder was very desirable. "Der Verlust," remarked Professor Musil,* "durch die in das Kühlwasser übergeführte Wärme ist einer der Grössten Mängel der Gasmachine in ihrer heutigen Entwicklung. Die Wasserkühling is unbedingt notwendig, so lange Arbeitscylinder und Verbrennungsraum vereint sind; wäre eine Trennung derselben praktisch durchführbar . . . . dann könnte diese Verlust vermindert, möglicherweise vermeiden werden." Deferred carburation permitted of a temperature separation, and, given a proper method of injecting fuel into an adequately heated volume of air, this method was greatly superior to the systems of pre-mixing now in vogue.

Fuel.—Several communications had been made on the subject of fuel, and the effect of water in the charge. Mr. Sennett's experiment (page 795) with water vapour rather bore out the results observed in the petrol motor, as recorded in the Paper (page 694). Possibly both results were also in some way connected with the phenomena observed by Berthelot and Vielle. They had found that the presence of a little steam, say 5 per cent., had a marked influence on the velocity of the explosion wave in carbon monoxide, increasing it from 1,090 or 1,264 to 1,700 inches per second, whereas more than 8 per cent. of steam had the opposite effect. The conclusion of the French scientists was that, at the temperature of ordinary combustion, the oxidation of the carbon monoxide was affected by the interaction of the steam. The whole question of the explosion wave in gas- and oil-engine cylinders and its effect on the combustion of the charge

* "Grundlagen der Theorie und des Baues der Wärmekraftmaschinen," 1902, page 701.

(Captain Longridge.)

was exceedingly complex and far too lengthy to discuss here. In the "Horseless Age" * Dr. C. E. Lucke recently gave the result of several years' experimental work in the study of the vibratory movements which always developed when a gaseous mixture was exploded. These were the chief causes of flame acceleration, and for reasons as yet insufficiently known, the effect produced was very variable. He (the author) had drawn attention to certain temperature phenomena in Professor Burstall's gas-engine experiments, which he attributed to explosion wave. If his theory was correct, it would be found that the curve of temperature loss would vary according to the shape of the combustion chamber, the nature of the fuel and the method of ignition, because the explosion wave varied with these factors. In the nature of the fuel, he included the presence of steam or water.

Mr. Holroyd Smith (page 808) blamed him for not telling them the proper quantity and mode of applying water; he wished he could. But he thought the long and careful experiments necessary might be undertaken by a Petrol Motor Research Committee.

Mr. Hemingway (page 845) had made a lengthy communication on the subject. He thought that this gentleman had quite misunderstood him. He (the author) had taken pentane for illustration purposes only. Everyone knew that petrol had other constituents, the main being hexane, heptane and octane. The communication contained many errors. The specific gravity of pentane should be 0·628. The calorific value was not 12,425 B.Th.U. (page 848), but more likely 20,499 B.Th.U. available. The other heat values, if based on the figure given would all be wrong. In equation (1), where was the other unit of oxygen? The results in (1) and (2) were impossible, because the petrol would be decomposed long before the temperature at which the water decomposed. The reactions under (5), (6), (7), could not exist, because the oxygen would at once combine with the carbon. But the broad line of reasoning was also quite wrong. Mr. Hemingway appeared to imagine that the chemical reaction hypothetically attributed by the

* "Horseless Age," 19 November 1902.

author to a very small portion (page 698) applied to the whole charge. That, of course, was the fatal error that made further discussion unnecessary. He could not agree that the diagram, Fig. 8 (page 697) was useless. It was exceedingly pertinent, because it showed that the splitting or dissociation of a charge into lighter and heavier constituents led to irregular burning. It also graphically established the fact that the rate of combustion for carbonic oxide was lower than for hydrogen; and that in the case of their mixture, the rate of burning, even in complete combustion, was not the mean of the two rates; but the two gases appeared to burn separately, each with its own rapidity of flame propagation. Hence the observed maximum pressure would not correspond to a uniform combination of the mixture. Nor could he admit that the Tables 1 and 2 (page 699) and diagram, Fig. 9 * (page 700), were useless. It was quite the reverse. Petrol constituents lay in the same series as kerosine, and the phenomena of combustion were strictly analogous. He feared Mr. Hemingway's suggestion of ether (page 852) as a substitute for petrol was impracticable. Just the same restriction as to carriage would apply to ether. The evaporation losses and dangers would be greater; while the cost of manufacture was far greater. There was first alcohol to be made, and then, from that, ether to be manufactured. His correspondent hardly appreciated the function of the so-called "enricher." The object was to add something that would cause quicker and better combustion of the petrol, or evolve, as picric acid for example, a larger volume of gas on ignition. He sympathized however with Mr. Hemingway, as he did with everyone who tried to find an improved fuel. What was wanted was a quick-burning fuel, giving no more heat than could be dealt with by air-cooling. To combine the required conditions of weight, power, and size with such fuel would, he thought, involve large light, thin

---

* In reply to Mr. Barcroft's query (page 843), Messrs. Tangyes had written:—"We have now examined a large number of diagrams, and find that the size of the gap varies considerably; but we do not think the slight difference in speed between the various engines is sufficient to account for the variation in the gap."

(Captain Longridge.)
steel cylinders, high compression, and impulse every revolution. He commended to chemists the fuel question, and asked them to remember that the possibilities of calcium carbide had not yet been exhausted; to metallurgists, he suggested the experimental determination of the best composition for steel cylinders; and to engineers the design of the impulse-every-revolution engine, the realization of which he thought lay on the lines of his own engine.

It was interesting to hear that both Mr. C. Wood (page 886) and Mr. J. Johnston (page 862) had obtained increase of power by water-injection, the latter nearly ten per cent., while at the same time avoiding the necessity for water-jacket cooling. The difficulties of adjustment in the water-feed appeared to have been quite overcome in the Banki motor and in the Priestman engine; and would be still less, if the water were in some way part of the fuel, as in the case of alcohol.

In answer to Mr. E. L. Orde's query (page 869), he would say that the petrol was introduced through the ordinary Daimler suction jet-carburator. The water leaked into the combustion chamber through a porous casting.

Ignition.—Mr. O'Gorman (page 817) misunderstood his suggestion (page 705) as to the points of firing. The object was to avoid a dead blow on the crank-pin. In the Simplex gas-engine, the charge was fired just after the commencement of the outstroke, instead of on the dead centre; the modification greatly reduced shock upon the working parts. If Mr. Sturmey referred to the Paper (page 709), he would find that he (the author) had pronounced control by varying the point of ignition to be wasteful, and, in the hands of an inexperienced driver, risky.

Governing.—It was evident that he (the author) alone criticized the system of volume throttling. In 1901, Mr. F. D. Howe had published * a series of explosion-engine diagrams, on which he remarked that throttle-governing "has the area, below the atmospheric line, chargeable against it, which may often amount to 7 or 8 per cent.

---

* "Horseless Age," 6 November 1901.

of the indicated horse-power of the engine." "The sudden change," he added, "from vacuum to pressure, in the compression line cannot be good for the inlet valve, as it must cause more or less slamming at high speeds." "Diese Methode der Regelung," says Professor A. Musil (*Ibid*,* p. 669) "ist allerdings sehr einfach; vom Standpunkte der Wärme ausnützung, jedoch höchst unvollkomen, und daher verwerflich," and this was precisely his own opinion.

Charge Expansion.—He agreed with Mr. Sisson (page 871) that the increased-expansion gear would probably wear badly, and was inapplicable to any but small motors; and was pleased to find they agreed on the matter of steel.

Fig. 44.
Bifurcated Exhaust.

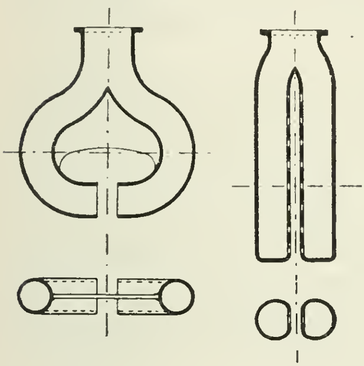
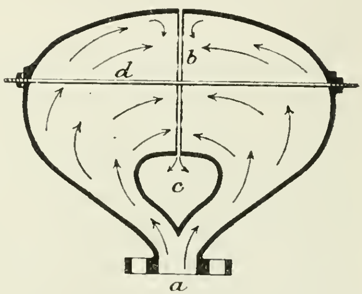


Fig. 45.
Silencer (Ronan).



Silencers.—The stress laid on silent running led him to make two further suggestions. The first was to cool and thus reduce, as much as possible, the volume of the exhaust, by leaving exhaust pipes unlagged, and possibly fitting them with radiating ribs. The second was to try whether there might not be something in the principle of mutual interference or destruction of the sound waves by the juxtaposition of double discharge openings into or from the silencer. The diagram above,† Fig. 44, showed a bifurcated exhaust, the two opposed currents impinging upon each other.

* *See* footnote to page 895.

† "Horseless Age," 29 October 1902.

(Captain Longridge.)

The same principle was applied in the A. G. Ronan's (Canada) silencer.* The muffler consisted of two hollow members, arranged with their exhaust mouths opposite each other, Fig. 45 (page 899). The gas entered through inlet *a*, passing each side, as shown by arrows. It then entered from opposite sides of the perforated hollow diaphragms *b* into the outlet pipe *c*; *d* was a baffle plate.

Change-Speed Gear.—The gain in power by its elimination was evinced by Mr. Lucas' statement (page 801); and also indirectly, by the fact that, in the recent Chateau-Thierry hill-climb, both the light and heavy-car events were won by vehicles with direct drive on the top speed, the motors being of lower power than many of the competing engines. He had long advocated both features, and believed that the car of the near future would be gearless, for which innovation the two-cycle motor was far better adapted than the Otto engine.

Lubrication.—Before dealing with comments on this subject, he might mention that, as regards the addition of water to the oil in the base chamber, he had noticed † that Mr. H. D. Meier testified to its efficiency as a cooling agent. It would also be remembered that Messrs. Priestman Brothers ‡ claimed that, owing to the reduction of temperature and the partial recondensation of the injected water, the friction between the piston and walls was reduced, and the escape of gas past the piston was diminished. He thought that makers who experienced cylinder cooling difficulties would find a remedy in adding water to the base chamber.

Touching the possibility of pre-ignition arising from lubricant vapour, Mr. H. S. Bult (page 844) had offered a very interesting explanation. He would not discuss this question further than to refer to one of the first of the gas-engine experiments at the Institution of Technical Physics, George Augustus University, Göttingen, reported by Professor Eugen Meyer in the Zeitschrift des Vereins deutscher Ingenieure, 1901, page 1,297. On varying the cylinder

---

* "Horseless Age," 12 November 1902, page 539.

† *Ibid.*, 23 July 1902.

‡ Patent 23582 ^{97}.

lubrication from one drop per second to nearly continuous flow, it was found that, with practically the same mechanical efficiency, the gas consumption decreased from 29 cubic feet to 23·2 cubic feet per B.H.P. hour, the load remaining constant. The tests showed that even at comparatively low wall-temperatures (61°–158° F.), lubricating oil was vaporized and contributed as fuel to the work done on the piston. Now it was known that heavy oil vapour, being less chemically stable, was readily ignited, so readily that, as Professor Robinson recorded, automatic ignition of petroleum vapour and air could be produced in the cast-iron vaporizer of the Hornsby-Akroyd engine, at a temperature such that the hand might be held on the metal without any unpleasant sensation. On the other hand, it had been shown both by the author and by Messrs. Carless, Capel and Leonard, and in recent experiments carried out by the Booth Cycle, Motor and Engineering Co.,* that petrol vapour and air would not ignite except by the application of a light. To these experiments he would refer Mr. H. M. Walker (page 878). Pressing these facts no further than to establish as certain that petrol vapour needed, for ignition, a far higher temperature than heavy oil vapour, was not the conclusion cogent that if the two vapours were together present in the cylinder the latter would ignite first? In other words, given the necessary conditions of compression and temperature, the firing of the heavy oil vapour of the lubricant might be a cause of the premature ignition of the petrol charge.

Mr. Bult again has given (page 844) an interesting and probable explanation of the reason why Messrs. Crossley Brothers found gas-engine oil unsuitable for oil-engine lubrication.

Mr. Suggate's experience with plumbago (page 874) for cylinder lubrication tallied with that of Messrs. Cario and Wagner. Their experiments † pointed to lubrication with pure graphite as the most desirable system, the least costly and the most cleanly. Where carburation was deferred until the end of compression, and loose-

* "Practical Engineer," 5 Dec. 1902, page 539.

† "Mittheilungen aus der Praxis des Dampfkessel und Dampfmaschinen Betriebes," 1902, page 53.

(Captain Longridge.)
headed cylinders were used, might it not be possible to fit a spring ring of plumbago on the piston head?

He was not sure that he could accept Mr. W. Scott Taggarts' distinction between the carbon deposits due to fuel and to lubricant (page 877). In the distillation of oil both soft soot and hard granular deposits were obtained; and he had found the latter on the outside of inlet valves, where of course no lubricant was present.

Mr. H. M. Walker (page 879) claimed economy in the use of grease instead of oil for change-speed gears. He (the author) could not endorse this. He had been for several years a manufacturer and patentee of railway axle-boxes, and had from the very first urged on railway companies the use of oil in preference to grease. Nowadays, scarcely a grease axle-box remained except on goods wagons, which were liable to receive less attention. In the first place, grease did not lubricate until melted by the heat generated through friction. In the second place, the removal of the solid hydrocarbons improved the lubricating properties of an oil. For cylinder purposes, too thin a lubricant meant waste; and too thick an oil meant friction from the lubricant itself. The best oil, therefore, was one with the lowest viscosity, consistent with economy, and the highest flash-point.

He thanked Mr. J. Veitch Wilson (page 882) for his interesting communication, which was the more valuable because of his long and varied experience with all questions of lubrication; and he hoped that all who had been in any way interested in the Paper would, from time to time, favour him with facts, theories and improvements relating to the motor-car industry.

He fully agreed with M. Mathot (page 862) as to the need of a recognised standard. He thought that the trade should sell motors only at their ascertained brake horse-power, at a given number of revolutions, and should also state the fuel consumption for that horse-power. M. Mathot had selected as his "modulus of power," the volume swept by the piston, divided by the constant 11,250, and said that of two motors giving equal power at equal revolutions, the better was that with the lower "modulus of power," in other words, that with the smaller volume swept by the

piston. He did not think that was quite correct, because it omitted the factor of fuel consumption. Possibly M. Mathot intended to include equal fuel consumption among the conditions in the above comparison.

PRESIDENT, 1892–93.

(Deceased 1898.)

The Institution of Mechanical Engineers.

PROCEEDINGS.

December 1902.

An Ordinary General Meeting was held at the Institution on Friday, 19th December 1902, at Eight o'clock p.m.; William H. Maw, Esq., President, in the chair.

The President said it was with very great regret that he had again to open the meeting by referring to a severe loss sustained by the Institution since its last gathering. As all the members knew, the Institution had since their last Meeting suffered an irreparable loss in the death of Sir William Roberts-Austen, who had been a sincere friend of the Institution. The work which the late Sir William Roberts-Austen did for the Institution in connection with the Alloys Research Committee rendered them deeply indebted to him. When that Committee was formed in 1889, Sir William was appointed the Reporter. The First Report was made in 1891, since when four other Reports had been made and published. The Sixth Report was in an advanced stage at the time of Sir William's death, and was now in the hands of those who had helped him. The work done in connection with the Alloys Research Committee was some of the most important work the Institution had carried out. It represented an amount of original work and original research which was unequalled by that of any other Research Committee of the Institution, and he need scarcely say that the greater part of the work was done by the late Sir William Roberts-Austen. At the Council Meeting of the Institution held that afternoon, it was decided to send

(The President.)

a letter of condolence to Lady Roberts-Austen, expressing their deep sympathy with her in her bereavement, and also expressing the great sense of indebtedness they all felt to Sir William for the work he had done. He was quite sure he would be authorised by the members to add their sympathies to those of the Council.

The Minutes of the previous Meeting were read and confirmed.

The PRESIDENT announced that the Ballot Lists for the election of New Members had been opened by a committee of the Council, and that the following one hundred and fourteen candidates were found to be duly elected :—

MEMBERS.

ASHTON, HAROLD THOMAS, D.Sc.,	Woolwich.
BONELL, THOMAS HENRY MAHADOO,	Kingston, Jamaica.
BROWN, HENRY,	London.
BUTLER, EDWARD,	Gateshead.
BUTLER, JOSIAH,	Landore, R.S.O., Glam.
DALE, JOHN,	Sunderland.
DONOHUE, WILLIAM EDWARD, Major A.O.D.,	Gibraltar.
KENRICK, JOHN ARCHIBALD,	West Bromwich.
KITCHING, ALFRED,	Singapore.
LIRONI, VITTORIO GIOVANNI,	Portsmouth.
MARSHALL, ROBERT,	London.
RENOLD, HANS,	Manchester.
SIMPSON, WILLIAM,	Aberdeen.
STEVENSON, GRAHAM MORTON,	Llanelly.

ASSOCIATE MEMBERS.

ABEL, WALTER ROBERT,	Leeds.
BALDWIN-WISEMAN, WILLIAM RALPH,	Southampton.
BAXANDALL, RICHARD FITZGERALD,	Wakefield.
BEIRNE, SIDNEY ANGELO,	Astillero, Spain.
BERRY, WILLIAM,	Kimberley, S. Africa.
BREWER, EDWARD GODFREY,	London.

Bullmore, Alfred William Ernest, .	London.
Chalmers, James, ...	Pernambuco, Brazil.
Craig, James, ...	Glasgow.
Dawson, John Edward, . . .	West Hartlepool.
Down, Percy Bissett, ...	Wolverhampton.
Dunt, Robert Archibald, . . .	Leeds.
Edwards, Arthur Octavius, . . .	Ceylon.
Etchells, Ernest Fiander, . . .	London.
Finnie, William, ...	Singapore.
Forga, Alfred, ...	Arcquipa, Peru.
Forward, Ernest Alfred, . . .	London.
Fraser, William Stuart, . . .	Bombay.
Gahagan, Roland Hayes, . . .	Bombay.
Goldarbeiter, Joseph Leonard, . .	St. Petersburg.
Gordon, Charles William, . . .	London.
Gott, Joseph Barraclough, . . .	Chester.
Graham, James Lindsay, . . .	Glasgow.
Green, Bernard Joseph, . . .	Kidderminster.
Griffiths, Harold, ...	Birmingham.
Hailey, Frank Percival, . . .	London.
Higginson, Frank, ...	Broadstairs.
Hope, Alaric, ...	Liverpool.
Hunter, Edgar Lafayette, . . .	Cardiff.
Leach, Robert William, . . .	Wednesbury.
Lewis, Fredrick William, . . .	Rugby.
Lindsey-Badcock, William, . . .	London.
Longley, Reginald, ...	London.
Lorimer, Alexander Smith, . . .	Glasgow.
Marrian, Arthur Edward, . . .	Chatham.
Mason, John Farrer, ...	Leeds.
McCaffery, James, ...	London.
McMahon, John Joseph, . . .	Manchester.
Mowbray, Frank Herbert, . . .	London.
Neal, Henry Andrews, . . .	Gainsborough.
Nicholson, Robert Jaffray, . . .	Manchester.
Owston, William Henry, . . .	Woolwich.

PALMER, WILLIAM DUKE, . . .	Glasgow.
RADCLIFFE, ARTHUR EDWARD, . . .	Horbury, Wakefield.
RANKIN, ERNEST ALFRED, . . .	Bourton, Dorset.
SIMPKIN, FRANK HENRY, . . .	Sheffield.
SMITH, EDWARD TURNER, . . .	London.
STEDMAN, GEORGE PERCY WILLIAM, . .	Reading.
SWAN, EDWARD MONTGOMERY, . . .	Cardiff.
TARVER, HERBERT HENRY, . . .	Colombo.
TATTON, ALBERT LIGHTOWLER, . .	Woolwich.
TATTON, FREDERICK THOMAS JOSEPH, .	London.
TAYLOR, ARTHUR, ...	London.
THOMPSON, STEPHEN JOHN, . . .	Wolverhampton.
TUNLEY, PERCY JAMES, ...	Woolwich.
TURNER, DOUGLAS, ...	Johannesburg.
WESTERN, HUGH, ...	Cairo.
WHEATER, ERNEST JOHN, . . .	Keighley.
WILE, JULIUS ISAAC, ...	London.
WILLIAMS, CHARLES JOHN, . . .	Birmingham.
WINCH, APSLEY BROOKE, . . .	London.
WINEBLOOM, ALBERT VICTOR, . . .	London.

ASSOCIATE.

CHANDABHOY, SHAPOORJEE NUSSERWANJEE,	Bombay.

GRADUATES.

ALLENSBY, CHARLES REED, . . .	London.
ATKINSON, REGINALD CHARLES, . .	London.
BACON, ERNEST LESLIE, ...	Liverpool.
BAKER, EDWARD, ...	Rotherham.
BARRY, LAWRENCE CATER, . . .	London.
BOULT, ERIC FRANCIS, ...	London.
BREWSTER, HAROLD JOHN, . . .	London.
CHATFIELD, KYRLE RUDSTON, . . .	Teddington.
CLARK, ROBERT GEORGE, . . .	Port Talbot.
CLARKE, ATHOL WILFRID, . . .	Birmingham.
COX, LIONEL MAIDSTONE RUSSELL, . .	Rugby.
DEWDNEY, WILLIAM GILL, . . .	London.

Dow, Harold Percy, ...	London.
Fife, Frank Gordon, ...	Potters Bar.
Ironside, Percy Humphrey, . . .	London.
Jantzen, Paul Hermann Hudden, . .	London.
Lightfoot, Kenneth, ...	Colchester.
Maw, Arthur Ernest, ...	London.
Mitchell, William George, . . .	London.
Nutton, Harry, ...	Bradford.
Petrie, Percival, ...	London.
Pink, Edward Sidney, ...	Harrow-on-the-Hill.
Ravenshear, Albert Edward, . .	London.
Roberts, George Robert Wesley, . .	Newcastle-on-Tyne.
Roberts, Walter Slingsby, . . .	Colchester.
Shaw, William Calvert, . . .	Huddersfield.
Smith, Sydney Abbott, . . .	London.
Thompson, John Archibald, . . .	London.
Thornton, Arthur Frederick, . .	London.
Tomes, John Percival, ...	London.
Wakeman, Charles, Jun., . . .	Birmingham.
Wakeman, Frederick, ...	Birmingham.
Wallis, Gerald Pearson, . . .	Woolwich.
Wiswall, John William, . . .	Runcorn.
Wood, Wilfred Pimm, ...	Coventry.
Wright, Frank Claude, . . .	Colchester.
Younghusband, Kenneth, . . .	Braintree.

Transferences.

The President announced that the following three Transferences had been made by the Council since the last Meeting:—

Associate Members to Members.

Pearce, Standen Leonard, ...	Manchester.
Price, Charles Graham, ...	East Borneo.

Graduate to Member.

Lander, Philip Vincent, ...	Buenos Aires.

The following Paper was read and discussed:—

"Recent Practice in the Design, Construction, and Operation of Raw Cane Sugar Factories in the Hawaiian Islands"; by Mr. J. N. S. WILLIAMS, *Member*, of Maui, Hawaiian Islands.

The Meeting terminated shortly after Ten o'clock. The attendance was 94 Members and 54 Visitors.

The Institution of Mechanical Engineers.

RECENT PRACTICE IN THE DESIGN, CONSTRUCTION, AND OPERATION OF RAW CANE SUGAR FACTORIES IN THE HAWAIIAN ISLANDS.

By Mr. J. N. S. WILLIAMS, *Member*, of Maui, Hawaiian Islands.

Design.

The rise of the cane-sugar industry in the Hawaiian Islands may be dated from the year 1876, when a reciprocity treaty between the Governments of the United States of America and the Kingdom of Hawaii permitted the entrance of Hawaiian raw sugars into the United States free of duty. About that time the labour laws of the Hawaiian Kingdom facilitated the entry of Asiatic labourers under contracts to the plantations for terms of years, whereby plantation owners and managers were enabled to produce cane very cheaply.

The sugar-houses of that date were not designed to secure a maximum return of finished product from the canes ground, mainly for the reasons that the raw material was cheap, and price of sugar was high; so that satisfactory returns on invested capital were obtained, in spite of manufacturing losses which would be ruinous at the present day. The expansion of the industry was rapid, but in later years the price of labour increased, making the cane cost more, and

the price of sugar declined, reducing the margin of profit; this compelled an improvement in the processes of manufacture, and at the same time in the methods of cultivation, as can be readily seen from the following comparison.

Twenty years ago the average yield of commercial sugar was about 9 lbs. per 100 of cane, and the average yield of cane per acre was about 25 tons. At the present day the average yield of commercial sugar is about 12 lbs. per 100 of cane, and the average yield of cane per acre is about 40 tons. The above averages are taken over the whole group, but there are individual plantations of great size, where the average yield far exceeds the above figures.

A detailed history of the steps in improvement in cultivation and manufacture of cane and sugar in the Hawaiian Islands during the past twenty-five years is beyond the scope of the present Paper, which describes the design, construction, and operation of the new sugar factory for the Hawaiian Commercial and Sugar Co., incorporated in San Francisco about twenty-five years ago. This company acquired from the Hawaiian Government an immense tract of land with its pertaining water-rights on the Island of Maui, and erected a sugar factory, which was then one of the finest in operation, making upwards of 100 tons of raw sugar daily.

With the lapse of years and change of conditions, it became necessary to remodel the systems of work to meet the altered circumstances, and the old factory being no longer adapted to handle the greatly increased crops, the task of designing and constructing the new sugar-house was placed in the hands of the Honolulu Iron Works Co. of Honolulu, an old established concern, whose intimate acquaintance with the requirements of the case, and previous successes in the construction of modern sugar factories, warranted the confidence placed in them by the Board of Directors of the Hawaiian Commercial and Sugar Co. The factory is designed to grind a maximum of 3,600 tons of cane per day of twenty-four hours, which quantity of cane, when at its best, will yield about 550 tons of commercial sugar of about 96 per cent. pure sugar. The amount of cold water required for the condensers of the vacuum evaporating and graining apparatus in the plant will reach 9 million

gallons per day; as this amount of water is sufficient to irrigate some 800 acres of cane, it became necessary to so situate the buildings that this water, after having been used in the factory, could be turned into the irrigating ditches below the mill site.

The handling of 3,600 tons of cane during daylight necessitated special arrangements of railroad tracks for storage of cane for night service, and so placed that the full cars would descend towards the scale houses, thus requiring the minimum of effort to move them. The immense quantity of cane to be handled required that the storage yard be approached from all sides; and the great area of the cane lands indicated a central position so as to reduce the average length of haul of cane. Since the finished product amounts to only one-eighth of the weight of the raw material, the question of shipment of sugar was a secondary one, and the other conditions being satisfactorily met, the sugar shipments were found to have been well provided for.

Having the foregoing considerations in mind, the new works, Plate 81, were laid out on a piece of waste land near the centre of the plantation at an elevation of 73 feet above the sea, about one and a half miles from the port and 15 feet below one of the principal irrigating canals, whence the supply of water for the condensers is drawn. The plot has a 1 per cent. gradient to and from the buildings, the surface soil being volcanic, mixed with huge boulders; the underlying stratum is an old lava flow of considerable depth, thus furnishing a site which not only met all the surface conditions, but gave a foundation for the buildings and machinery that could not be surpassed.

Buildings.—The buildings, Plates 82 to 88, are of steel construction, covered with corrugated iron, and occupy a space approximately 300 feet by 400 feet square; the grinding mills have each their own house, the houses extending over the boiler plant; the clarification, filtration, concentration and graining apparatus are contained in two buildings side by side, each having the requisite floors and supporting columns for the machinery designed and built in with the main structure. The columns are all carried upon concrete foundations built upon bed rock, none of these

foundations being loaded to more than 3 tons per square foot at the base, the outer columns of building being carried upon a continuous wall of concrete, on the outer side of which, gutters 3 feet wide and 1 foot deep are fixed to carry off the rainfall on the roofs. The ground floor of the building is of concrete, 6 inches thick, in which are situated all the necessary drains and gutters for washing down the various apparatus. The buildings are lighted by glazed sashes on the sides and ends, and fixed skylights in the roof, some 30 per cent. of roof surface being skylight, and some 25 per cent. of vertical surface being glazed; the sashes do not slide, but open by swinging on trunnions, a form of construction that should not be used where severe rain-storms accompanied by high winds occur, as the sashes cannot be kept water-tight. The buildings are painted with a neutral tint graphite paint inside and outside, while the exterior surface of the roof is painted with a mixture of coal tar and red lead put on boiling hot.

Machinery and Apparatus.—The machinery and apparatus, when complete, will consist of—

3 sets of crushing mills, Plate 84, and Fig. 8, Plate 87, each of capacity to grind 1,200 tons of cane per twenty-four hours.

20 boilers with individual furnaces and fuel feeders, Plate 83.

2 sets of conveyors and carriers for elevating and distributing the cane refuse to the furnaces.

Clarification plant.

Filtration plant.

2 quadruple effect evaporators of the Lillie system, Plate 86.

6 vacuum pans, Plates 85 and 86, and Fig. 10, Plate 88, each capable of making 100 tons of dry sugar per day.

30 crystallizing tanks, Plates 85 and 86, and Fig. 10, Plate 88, of the Bock system.

20 centrifugal machines for drying grained sugars.

Elevators, conveyors and bagging apparatus for handling the finished product.

The following is a detailed description of the machinery and apparatus, taking the course of the cane as it leaves the gridiron of storage tracks, and the juice as it leaves the crushers.

The cane as it is cut in the field is loaded upon cars, 7 feet wide by 12 feet long, each having four wheels and running on tracks of 3 feet gauge; the end of the cars are boarded up, and each side is formed of 3 removable stakes set in sockets so designed that the stakes are readily cast loose.

After passing the scale house, Plate 81, where each car-load of cane is weighed, the cars are brought up to the cane carrier, one on each side; the inward stakes are removed and the cane discharged by the automatic cane unloader, which consists of a triangular framed structure carrying four moving endless chains with fingers, and capable of being raised to allow a car-load of cane to pass under, and then lowered until the fingers or rakes on the chains reach the cane and pull it off the cars in such quantity as may be needed. There are two of these cane unloaders, one on each side of the cane carrier, and the combined action of the two is sufficient to unload the cane as fast as the crushing apparatus can receive it, Fig. 3, Plate 82. After the cars are emptied they are run forward to a turn-table, making room for the full cars behind them, and are then directed to the empty car tracks; the stakes are replaced, and the cars weighed for the tare and then run forward to the tracks for making up the trains of empty cars, Plate 81.

Crusher and Mills.—The cane being discharged on the carrier is conveyed forward and upward until it reaches the preliminary crusher, which consists of two rollers, 26 inches diameter by 72 inches long, set vertically one above the other, Plate 87. These rollers are of solid cast steel and have zigzag grooves about 2 inches deep and 6 inches pitch, running lengthwise of the rollers; these grooves or teeth mesh into each other, draw in the cane, partially crushing it, and partially cutting it up into about 6-inch lengths; after passing the crusher, the mass then slides down an iron apron into the jaws of the first three-roller mill, Plate 84, where it is crushed under a pressure on the top roller of 230 tons applied by hydraulic rams acting on the brasses of the top roller. After passing this mill, the crushed cane is sprayed with hot water, and carried by an endless apron conveyor, made of steel slats on chain belting, to the jaws of

the second mill, which is a duplicate of the first but operating under a pressure of 320 tons on the top roller. The crushed cane, on being discharged from the second mill, is again sprayed with hot water, and by a travelling apron, a duplicate of that between the first and second mills, is conveyed to the jaws of the third mill, which is of the same size as the first two, and operated under 400 tons on the top roller, Plate 89; here the cane gets its final crushing, discharging the bagasse in the condition of fine shreds containing from 44 per cent. to 48 per cent. of moisture and from 7 per cent. to 9 per cent. of the sugar originally in the cane.

The crushing mills, Fig. 8, Plate 87, consist of cast-iron rollers, 34 inches diameter by 78 inches long, keyed to hammered iron shafts, 18 inches diameter in the roller, and having journals 15½ inches diameter by 20 inches long; the rollers are carried in heavy cast-iron housings fitted with suitable bronze bearings; the returner bar is a very strong cast-iron beam, pivoted on trunnions at the bottom of the housings, and drawn up against the front roller by two large bolts which extend outside the housings, so as to be easily accessible. Since this returner bar or knife is what passes the crushed cane from the front roller to the back roller under the top roller, it is subjected to very heavy strains, and requires careful adjustment to avoid setting up undue friction.

The mills and crusher are operated by one Corliss engine, Fig. 7, Plate 87, cylinder of 30 inches diameter by 60 inches stroke, running at 44 to 54 revolutions per minute. The speed of the engine is reduced through a train of compound gearing very strongly constructed, the pinions of which are of cast steel, and the wheels having cast-steel solid rims bolted to cast-iron spiders, the pinions being shrouded to the tops of the teeth, while the wheel teeth are bare. The first motion pinions and spur wheels have teeth 4½ inches pitch by 14 inches face, the second motion pinions and spur wheels have teeth 4½ inches pitch by 18 inches face, all mounted on hammered iron shafts, carried in cast-iron pillow-blocks which are lined with Babbit metal. The proportion of the gearing is such that, when the engine is running at 45 revolutions per minute, the peripheral speed of the crusher rollers is 28 feet per minute,

that of the first mill is 20 feet, the second mill 23 feet, and the third mill 26 feet per minute. The object in thus giving increased peripheral speed to each mill in the train is to reduce the thickness of the blanket of crushed cane going through each mill in the series, so that the increased pressure upon the top roll in each mill acts upon a thinner blanket and thus produces a better extraction with a given pressure.

Bagasse Conveyors.—The refuse of the cane, or bagasse, after leaving the last mill is received on an inclined elevator, consisting of link belt chains connected by wooden slats or scrapers, which catch the bagasse as it leaves the mill and elevate it up to a horizontal conveyor at a height of about 25 feet above the floor and inside the boiler-room. This horizontal conveyor runs across the building, and is designed to serve the two longitudinal carriers which distribute the bagasse to the furnace feeders.

Boilers.—For the ultimate capacity of the sugar-house there will be required 20 boilers, of which 14 have been placed, Fig. 4, Plate 83. These boilers are 7 feet diameter by 20 feet long, furnished with 118 tubes, 4 inches outside diameter; heads are $\frac{5}{8}$-inch thick, shells $\frac{9}{16}$-inch thick with treble-riveted butt joints, designed to carry 125 lbs. pressure of steam. They are arranged in two lines—ten on one side and four on the other; the boilers are set in brick, with a special furnace in front of each one designed for burning the low grade fuel furnished by the cane. The grate surface as originally designed was 49 square feet for each boiler, but it has been reduced to 36 square feet with very beneficial results. The heating surface of the boilers is 2,600 square feet for each, and ratio of grate surface to heating surface was 1 to 53, but is now 1 to 72. Each battery of boilers is served by a steel chimney lined with brick; height of chimney above lower grate bars is 180 feet, diameter of chimney inside lining is 11 feet 10 inches, the connection from boilers to chimney being made by a sheet-iron flue lined with brick. The temperature of the waste gases leaving the boilers was expected to be approximately 450° F., but in practice exceeded this limit.

Furnaces.—These furnaces are of the Dutch oven type fitted with a combination of grate bars set above one another in a series of steps across the furnace, the angle of incline being 47° with the horizontal, and ordinary grate bars situated at the foot of the incline running lengthwise of the furnace. The furnace as originally made is 5 feet 9 inches wide, having 23 step-ladder bars, supported at foot by a heavy transverse bearer, which also supports the flat ordinary bars of 2 feet 2 inches length. The reducing of the grate surface was accomplished by building up the ash-pit on each side underneath the step-ladder bars to a width of 4 feet. Strictly speaking, this is not a reduction of grate surface, since the surface for the reception of the fuel remains as originally designed, the actual reduction taking place in the area of the air-passages through the bars; it is however at this stage more convenient to refer to the matter as a reduction in the grate surface.

On the top of the furnaces are situated the bagasse feeders, which are iron boxes connected to the shoots coming from the overhead carrier, and in which are placed iron flap-doors, so arranged that the opening to the furnaces for the delivery of bagasse can be adjusted at will. The bagasse being delivered from the inclined elevator from the mills, to the horizontal cross conveyor in boiler house, is then conveyed and delivered into the longitudinal distributing conveyors over the furnaces. These conveyors have in the floor of the trough an arrangement of doors sliding across the trough, closing in the middle and opening both ways from the centre over each furnace, and operated from the firing floor; and by manipulating the opening of these doors, the supply of bagasse to each furnace is regulated. Under each of these doors is a two-legged shoot, one leg delivering to the furnace feeder, and the other to the floor for surplus bagasse, a flap in the shoot operated by a lever and chain throws the whole or any part of the bagasse either to the furnace or the floor, Fig. 9, Plate 88. The bagasse falls in a steady stream on the sloping grate surface beneath the outlet from the feeder, and rolls down the incline, burning as it falls, resting finally on the foot grates where the most intense heat is generated, and where the ash and slag formed by the combustion of

the bagasse remain until removal. The ashes and slag are removed from below the grate bars, and taken out through the air-passage to the furnaces underneath the firing floor.

The ranges of boilers are served by direct-acting plunger feed-pumps of ample capacity; there are two feed-pumps, to provide against accidents. These feed-pumps draw from a hot-well into which all the condensation throughout the house is returned; thus the feed water is distilled, and at a temperature of not less than 180° F. The feed make-up is taken from the condensation in the evaporator.

Juice.—The juice expressed from the cane by the action of crusher and mills falls into the receiving pan underneath the mill housings, and runs thence to an automatic screening apparatus, consisting of a chain elevator having slats which drag across a brass screen 14 inches wide and 10 feet long, pierced with 144 holes per square inch, holes about $\frac{1}{25}$th inch diameter; the screened juice falls through the screen into a receiving tank capable of holding 1,000 gallons, and is pumped from thence up to the juice-weighing machine, Fig. 12, Plate 90, which is situated over the liming tanks on the same level as the vacuum pans, while the screenings are taken up by the slats and delivered back to the mill for recrushing. This apparatus is driven from one of the second motion shafts in the gearing of the mill. The juice then passes over the weighing machine, is weighed in parcels of about 400 lbs., sampled, and then dropped into the liming tanks, where it is treated with lime and other reagents, and then pumped through a high-pressure heater, where it is brought up to about 230° F. under the corresponding pressure, cooled down to 205° F. in a tubular cooler, which admits of cold juice being pumped through in one direction while the hot juice is being pumped through in the opposite, the cold juice taking up the surplus heat in the hot juice, thus effecting an economy of heat.

After passing the heater, the juice is discharged into a series of settling tanks, where it is allowed to stand until the impurities settle out, when the clear juice is drawn off into a receiving tank for juice filters, and the settlings, after being diluted with water and further

treated with lime and re-agents, are drawn off into a receiving tank for the filter presses, when the solids are finally separated from the clear juice they held back; the solids are discharged into the sewer to be mixed up with the irrigating water and used as fertilizer for the cane fields, while the clear juice is discharged into a receiving tank for the evaporator. The clear juice from the settling tanks is passed through sand filters, which consist of cylindrical tanks, set on end, with an internal tube covered with fine wire gauze, and the remainder filled with ordinary sand, the juice percolating through the sand into the internal tube and thence to the receiving tank for the evaporator.

Evaporating Apparatus.—This is quadruple in effect, the first body which receives the thin juice being supplied with exhaust steam from the various engines in the sugar-house, under about 5 lbs. pressure. The steam given off from the thin juice in the first body is used in the second body to evaporate further the slightly thickened juice coming over from the first body, and so on to the fourth body, which works under 27 inches of vacuum; this vacuum is produced by the condensation of the vapours given off from the syrup in the last body, a powerful vacuum pump being connected to the condenser to draw off air and uncondensable gases, which come over with the vapours from the juice or, as it is now called, syrup. The juice containing some 16 per cent. of solid matter in solution enters the apparatus, and is discharged containing some 60 per cent. of solid matter; this syrup is pumped up to the receiving tanks for the vacuum pans, having lost in the operation about 75 per cent. of the water originally contained in the juice. The greater portion of this water, which is delivered by the evaporating apparatus in a pure state, is used for feed make-up for the boilers, for washing down tanks, filters, etc., and for diluting the settlings from settling tanks and molasses when being treated for reboiling, the surplus going into the sewer, and out on the fields for irrigation. The evaporator in use has a forced circulation for the juices and syrups between the various bodies, and is furnished with 538 copper tubes, 3 inches diameter by 7 feet 4 inches long, corresponding to 3,050 square feet heating surface

in each body, or a total heating surface of 12,200 square feet, evaporating for every pound of steam taken into the first body approximately 3·75 lbs. of water out of the juice, and approximately 5 lbs. of water per square foot of heating surface in the four bodies.

The evaporating apparatus is of the type known as film evaporators, since the juice under operation showers down over the heating surface in a spray, the steam being inside the tubes. The circulation of the juice over the heating surface, and from body to body, is maintained by a series of centrifugal pumps, one for each body, all driven by a high-speed engine directly connected to the shaft upon which the centrifugal pumps are mounted. The syrup is drawn off from the evaporator, and delivered into a receiving tank by the action of the circulating pump connected with the last body of the apparatus; from the receiving tank an independent steam-pump draws the thick syrup and forces it up to storage tanks of about 25,000 gallons capacity situated on the vacuum pan floor, and at such a height that they drain to the pans. These tanks serve a main-supply pipe to which each vacuum pan is connected.

Vacuum Pans.—These pans, Plate 86, and Fig. 10, Plate 88, are each 10 feet 6 inches diameter, with a conical bottom, straight belt 15 feet high and dome-shaped cover, connected to the condensers by 48-inch cast-iron pipes, and are fitted with 1,000 square feet of heating surface each, divided over sixteen 2-inch copper coils, set 6 inches apart from coil to coil, and properly supported on iron beams, being held thereto by brass clamps; these admit of a certain amount of movement in all directions to accommodate the contraction and expansion of the coils. The coils are served by both live and exhaust steam, and drain into manifold pipes, whence the water of condensation from the steam used in the coils is drawn by pumps and delivered to the hot-well to be returned to the boilers. The delivery gate at bottom of pan is 30 inches diameter and is of the mushroom-head type, being operated by a worm and wheel from the upper platform, the final tightening being effected by a toggle operated by the same worm and wheel. The joint is made by a ring of hard rubber on the gate, which seats against a turned rim on the pan bottom; the

ring is easily removed and replaced when worn, spare rings being carried in stock for the purpose. The pans are operated under 27 inches of vacuum, which is maintained by the vapours being condensed in a suitable jet condenser, to which is attached a powerful vacuum pump, the water used, together with the condensation of the vapours, escaping through a tail pipe out into the main sewer.

The cooked sugar, or massecuite, after being boiled and grained, is dropped into a receiving tank or mixer, to which are attached the centrifugal drying machines of the suspended type, having baskets 40 inches diameter lined with fine brass screens, and revolving at 1,000 revolutions per minute. Each machine is charged by opening a gate in the bottom of the mixer, and allowing a quantity of the massecuite to run into the baskets of the centrifugal machines, which are kept at a slow motion until sufficient material has been received. They are then brought up to speed in about one minute, the centrifugal force generated in the molasses driving it out through the screen, leaving the grained and dry sugar in the machine, which is then discharged through the bottom by raising a valve; the whole operation occupies about eight minutes, and the amount of dry sugar recovered per charge is 400 lbs., so that each machine dries 3,000 lbs. of sugar per hour.

These machines are driven by Pelton water-wheels, 23 inches in diameter, mounted on the spindle just below the point of suspension, and are served by two nozzles delivering water under 180 lbs. pressure, one nozzle being to keep the machine at speed when attained, and the two nozzles to furnish sufficient pressure water to bring the loaded machine up to its maximum speed of 1,000 revolutions per minute in the space of about one minute. To effect economy of pressure water, after the maximum speed has been reached, one nozzle is shut off. The pressure water is furnished by one large direct-acting pump delivering 1,000 gallons of water per minute into an air-chamber 60 feet high. It is found that the centrifugal machines require water under the steadiest possible pressure to get the best results; the air-chamber is accordingly charged with compressed air at 60 lbs. pressure before the water-pump is started. This gives a very long air-cushion in the head of the

stand-pipe under 180 lbs. pressure, which corrects the irregularities due to slight variations in the speed of the supply pump, and gives time for the pump regulator to act in slowing down or speeding up to accommodate the machine service.

After the sugar has been discharged from the centrifugal machines, it falls into a screw conveyor serving the battery of machines, and is conveyed to an elevator which carries the sugar up above a large bin holding about 100 tons of sugar; the warm sugar falls on the vanes of a rapidly revolving fan which scatters the sugar all over the bin, breaking up the lumps, separating the grains of sugar one from the other, and cooling it; the object of this is to improve its keeping qualities on the voyage from Hawaii to San Francisco or New York, it having been found that sugars bagged warm are more liable to deterioration on a long voyage than those treated as above. From the bin, which has an inclined bottom, the sugar is drawn off through spouts, then it is bagged, weighed, and stored for shipment. An economy in labour is also effected, as by the use of the bin one man bags and weighs 50 tons of sugar in ten hours, whereas when the sugar has to be shovelled into bags from the floor it requires three men to do the same work.

The above sugars, being made directly from the syrup, are known as No. 1 sugars, and the molasses given off in the drying process is No. 1 molasses, which, on leaving the centrifugal machines, is caught in a tank where it is diluted with water to melt out any small grain that may have escaped through the screens, brought up to boiling point and pumped up to storage tanks on the vacuum pan floor; these tanks have a capacity of about 18,000 gallons, and are connected to the vacuum pans in the same way as the syrup tanks. This molasses is boiled in a vacuum pan to grain, and if it should be too poor in sugar, a little syrup is taken in with it to start a grain, and this grained molasses is then discharged into a similar tank or mixer to that used for No. 1 sugar, and dried in centrifugal machines of the same kind and size as those used for No. 1 sugar, but the resulting dried sugars are of a smaller grain and poorer quality, and cannot be operated upon in the same way as No. 1 sugars, and are therefore discharged on the floor, bagged, and weighed direct.

This sugar is known as No. 2, and rarely exceeds in quantity 25 per cent. of the No. 1 sugars. The molasses from this sugar is known as No. 2 molasses, and is treated in tanks in a similar manner to the No. 1 molasses, being pumped up to storage tanks of 12,000 gallons capacity, and when sufficient has been accumulated, a boiling is made in one of the vacuum pans. This molasses is, however, very poor in sugar and requires special treatment to obtain the crystals, failing which it cannot be marketed; it is boiled to a density of from 83 per cent. to 88 per cent. of solid matter, depending greatly upon the character of the solids in solution, and is then discharged from the pan to a crystallizer, which is a tank 9 feet in diameter by 20 feet long, fitted with an internal shaft and stirrers. It has been found that when crystals of sugar are formed in a poor molasses, if they can be kept moving about in the solution, they take up more pure sugar therefrom than if they remain stationary. Consequently after the charge of molasses is in the crystallizer, the grain, which forms as the charge cools down, is kept in motion by the action of the stirrers, which revolve very slowly; after having been in process for a period varying from eight to sixteen days, all possible sugar has been taken up—a point which is determined by drawing off samples of the contents of the crystallizer, from time to time and analyzing.

The crystallizing tanks are situated above the mixer and centrifugals and below the vacuum pans, so that a boiling of molasses descends by gravity to the crystallizer, and thence by gravity to the mixer, Plate 85.

This massecuite is dried in the same way and by similar machines to other grades of massecuite, but the resulting sugar which is of too low a grade to ship is drawn into the vacuum pan while boiling No. 1 sugar, and is thus converted into No. 1 sugar. This is done by putting the low goods dry into a conical bottomed tank connected with the vacuum pan by a short pipe and gate; by opening the gate, when vacuum is on the pan, the dry sugar is drawn in and immediately mixes with the grain already in the pan. Care is taken that the grain in the pan shall be no larger than the grain to be drawn in, so as to avoid irregularities which would tend to affect the

market value of the product. The molasses given off from the low goods from the crystallizer is carefully analyzed, and if so poor in sugar that it will not pay to reboil, it is discharged over a weighing machine, and is either burned in the furnaces with the bagasse, fed to stock with their green food, or mixed with irrigating water and run on the land as a fertilizer; if of a good enough quality it is mixed with No. 2 molasses and treated with it. Molasses has a definite calorific value, and careful observations have made it equal to bagasse as fuel. Three tons of bagasse containing 45 per cent. moisture are considered in the Hawaiian Islands as equal to one ton of ordinary Australian coal, consequently one ton of molasses properly burned is equivalent to one-third ton of ordinary coal. The burning of the waste molasses is accomplished in this factory by feeding it in thin streams on the bagasse as it is ejected from the last mill; the bagasse soaks up the molasses in a very finely divided form, and it burns readily and produces a very hot fire in the furnaces already described. The amount of molasses burned varies from 60 to 200 gallons per hour, depending upon the rate at which the waste molasses comes forward.

When the molasses is used for fertilizing purposes it must be dissolved in about fifty times its volume of water, otherwise it may destroy the plant; it is not considered a very safe proceeding, but applied with care there is no doubt of the value of molasses as a fertilizer on certain lands.

The finished product is divided into two grades A and B.

Grade A includes all No. 1 sugar, and is high-class raw sugar having a hard clearly defined crystal, and of a purity of from 97 per cent. to 98·5 per cent. This sugar does not deteriorate in transit to market, if care in manufacture has been taken; as a rule it will dry out somewhat, losing slightly in weight, but this is compensated for by the rise in purity which is usually in the proportion of the drying out.

Grade B includes all low-class sugars whether made from syrups or molasses; the crystal is soft, is not clearly defined, and the purity ranges from 93 per cent. to 96 per cent.; this sugar will lose in weight and polarization in transit owing to the tendency to sweat

and ferment, due to the poor grade of material from which it is made.

The sugars are put up in 125-lb. bags and are loaded at the sugar-room on flat cars, 200 bags to the car, for transit to the port, where they are loaded on scows from which they are shipped.

Water-Supply.—As already pointed out, the water on this plantation is valuable for irrigating purposes, and in the design of this sugar factory care was taken to economize in this direction in every way possible. The level of the water in the irrigating canal is 15 feet higher than the ground floor of the sugar-house; and as unnecessary pumping is undesirable, the condensers are all furnished with barometric columns or water legs, 40 feet long, so that the injection water drains away by gravity from the condensers, leaving for the air-pumps the work of drawing off the air and uncondensable gases given off from the syrups under operation. The water is brought down from the factory in a wrought-iron pipe 40 inches diameter, 2,000 feet long; at the buildings, this pipe is brought up out of the ground and carried through the building at 12 feet above floor level; a receiving cistern in the floor of the house, 15 feet deep and 12 feet diameter, was constructed, and a 24-inch sewer-pipe was led out of this 8 feet below floor level; this sewer-pipe discharges into an irrigating ditch 1,500 feet away, which happens to be at such a level that the sewer can be given fall enough to carry off the water used in the factory. Finally the condensers are situated at such a height that they have to lift water about 12 feet in vertical height, the injection pipe on each condenser being connected to the 40-inch main supply-pipe; the water-legs of the condensers are all led into the cistern and carried down some 6 feet below the level of the sewer-pipe, so that they are always sealed against the entrance of air; the height from surface of water in cistern to bottom of condenser is 34 feet, and since the condensers are operated under 27 inches of vacuum, this gives a sufficient fall to allow the injection water to drain away by gravity against the vacuum.

The reason that such a large diameter is given to the supply-pipe is to reduce the loss of head by friction to the lowest practicable

point, since whatever head is lost in the supply-pipe due to friction has to be made up by the condensers lifting the injection water higher. Experience has proved that while theory shows that water can be lifted by a condenser 20 to 24 feet, when the condenser is serving a vacuum-pan or similar apparatus, 12 feet is the limit of lift that should be allowed, and then only under exceptional circumstances, because if the pan when boiling a sticky and intractable syrup or molasses should happen to get hot and lose its vacuum, it would be impossible to recover its position without cooling down, which would mean loss of time and difficulty with the product.

To provide against any such emergency, and also to provide pressure-water through the house, an 8-inch pipe-line is laid up to another irrigating canal, situated at a level of 300 feet higher than the mill site nearly 4 miles away; and from this pressure-pipe a 3-inch emergency pipe is led to each condenser, thus taking care of almost any contingency that may arise. To economize water still further, a pumping plant and pipe-line is arranged to return a portion of the water used in the factory back to the irrigating canal, from which it is drawn. This pipe-line is 24 inches diameter inside, and is made of wooden staves banded together with iron hoops, and delivers into the canal some 50 feet down stream from the point where the water enters the main supply-pipe. This was done because there are times during droughts when the water has to be distributed over great areas in order to keep the cane from drying up, but the plant is very seldom used, and was put in for insurance purposes.

Electric Lighting Plant.—The factory is served by a 50-kilowatt Westinghouse generator, driven by a direct-connected Westinghouse standard engine; the full load of the machine is 400 ampères at 110 volts. There are eight separate circuits, each having its own switch on the switchboard; the plant is fitted with lightning arresters, automatic circuit breakers, and the most modern types of fittings. The wiring throughout the factory is of extra heavy insulated copper wire carried on wooden bolsters bolted to the steel columns of the

structure; the factory is fitted with 700 incandescent lamps of 16-candle-power, the outside circuits serving the storage tracks for cane have 40 incandescent lamps of 100-candle-power on poles, 24 feet high set at 75 feet apart, the light from the lamps being concentrated by conical hood reflectors which direct the light downwards in a belt about 100 feet wide along the line of switches of the storage tracks. Incandescent lamps are used in preference to arc lamps, mainly because the small mechanism connected with the arc lamp would become deranged by a fine red dust which prevails during the dry season, and which sifts into everything, causing in the case of arc lamps a great deal of trouble to keep the gear clean and in working order.

Elevators, &c.—For the use of the workmen in going from floor to floor, a hydraulic passenger elevator is fitted reaching from the ground floor to the vacuum-pan floor, with a landing at the crystallizer floor. This elevator is worked by water from the pressure-pipe, which always has from 60 to 100 lbs. pressure available for use. An elevator for lime and stores is fitted on the outside of the building, reaching from the ground floor to the lime-room on the same level as the vacuum-pan floor, and is driven by belting and gearing from the shaft operating the crystallizers.

A well-fitted laboratory is provided on the filter-press floor, where the chemist is centrally situated.

Repair Shops, &c.—These are situated in the buildings underneath the sand-filter floor, but the large roll-turning lathe is situated under one of the 15-ton travelling cranes which span each mill-house. The machine shop is fitted with all modern tools, consisting of large and small lathes, shaper, planer, radial and pillar drill presses, bolt and pipe machines, and a full supply of bench tools, and is capable of dealing with any repair work that may be required for any part of the plantation. Carpenters' and blacksmiths' shops are also situated in the buildings, while the repair shop for cane cars is situated outside in a shed which spans one of the tracks specially devoted for this purpose.

For the supplies of all kinds needed on the plantation a large warehouse is in course of construction in a convenient place; attached to this will be offices for storekeeper and timekeeper. Near the warehouse will be situated a railroad platform and scales for the purpose of weighing out the carloads of sugar as they are hauled away from the factory, thus providing a double check on the sugar weights before leaving the premises.

The arrangements all through this plant are designed for making the greatest quantity of sugar in the shortest possible time, and with the least possible labour.

Construction.

The construction of this plant was practically begun in October 1900; some clearing and excavations had been done previously, but a permanent force of men, under the supervision of the superintending engineer, were actively engaged in this month, the arrival of material commencing in November 1900, and in February 1901 the foundations were far enough advanced to commence the erection of the buildings. The construction of the structural part of the buildings was completed in September 1901, and in October 1901 the sheet-iron covering for roofs and sides of building was completed. The machinery commenced to arrive in May 1901, and was immediately put in hand, the foundations and bolts having been made and set from special drawings. All the foundations throughout were made of concrete in the proportion of one barrel of cement, five barrels of sand and six barrels of crushed rock, this amount of material making $\frac{7}{8}$ cubic yard of concrete. This was well rammed in boxes properly laid out, where foundations came above the floor line; two inches next the boxes was filled with fine concrete made of one barrel cement, three barrels of sand, and four barrels of fine rock-screenings, to give a good finish to the exposed foundations. All bolt-holes were left 3 inches larger than the bolts, and were filled with cement grout when machinery was placed. Boiler settings were made of hard red brick with fire-brick linings; all fire-brick arches over furnaces and other places were made of specially selected brick put in dry, bricks being cut and fitted to radius required; fire clay was very sparingly used on

the vertical linings; no stay-bolts of any kind were used in the brickwork, the thrust of arches being taken up on heavy walls, and the boilers hang 2 inches clear of brickwork in all directions, the space being filled up with asbestos packing. This method of construction permits the free expansion and contraction of the boiler without throwing any strains on the enclosing brickwork, and has proved excellent.

The steam-pipes throughout the plant were made of lap-welded steel pipes tested at the factory to 500 lbs. per square inch. They were joined by heavy cast-iron flanges bored out, driven on to pipes which were then expanded into the flanges by riveting; the projecting ends of pipe were riveted down and cut off flush and straight. All elbows and tees are of cast-iron, large sizes being flanged, and small sizes screwed. The piping itself is designed with free ends to avoid the use of expansion joints, the main pipe lines being solidly anchored near the middle of the buildings to convenient columns, and hung from the floor beams so as to be free to expand outwards from the centre. In one instance only an expansion joint was placed, as the ends of the pipe were locked between columns, and means for taking up the expansion at this point became necessary. The steam-pipes are all covered with non-conducting jackets; the small sizes from 4 inches diameter down have magnesia covering 1 inch thick. The larger pipes up to 18 inches diameter have air-space covering made of strips of wood 1 inch by 1½ inch laid longitudinally and 3 inches apart; over this was wire-netting of ½-inch mesh, then three layers of heavy manila paper, and the whole covered with cotton cloth and whitewashed.

The material used in the construction of this factory is as follows:—

Concrete in foundations and floors	8,000 cubic yards.
Steel and iron in buildings	3,000 tons.
Machinery	2,500 tons.
Lumber in floors, &c.	250,000 feet B.M.
Glass for windows and skylights	8 tons.
Paint	3,500 gallons.
Bricks in boiler settings and chimney linings . . .	500,000.
Railroad tracks in storage yard	6 miles.

Statement of men employed, and time occupied in construction is as follows:—

On buildings,	skilled	7 men	8 months.
,, ,,	unskilled	85 men	8 months.
On machinery,	skilled	20 men	10 months.
,, ,,	unskilled	100 men	10 months.
Foundations and sundries,	skilled	2 men	14 months.
,, ,, ,,	unskilled	30 men	14 months.
One superintending engineer			16 months.
One draughtsman			14 months.
One receiving and shipping clerk			16 months.

The design and carrying out of this work is due to the Honolulu Iron Works Co., the responsible man being Mr. C. Hedemann, the manager; owing to the short time given to complete the work, the bulk of the material and machinery was constructed in the United States to specifications drawn up by the Honolulu Iron Works Co. Messrs. Milliken Brothers, of New York, supplied the buildings; the Kilby Manufacturing Co., of Cleveland, Ohio, supplied the vacuum pans and crystallizers; the American Tool and Machine Co., of Boston, Mass., furnished the centrifugal machines, under the patents of Messrs. Watson, Laidlaw and Co., of Glasgow; the Sugar Apparatus Co., of Philadelphia, furnished the evaporating apparatus; the Link Belt Machinery Co., of Chicago, furnished the elevators and conveyors for bagasse, etc.; the vacuum pumps for the vacuum pans and evaporating apparatus were furnished by the Blake Manufacturing Co., of Boston and New York, and Messrs. Guild and Garrison, of Brooklyn; while the Honolulu Iron Works Co. supplied the mills, boilers, and sand filters. The remainder of the machinery, such as tanks, large steam-pipes, water-pipes, etc., was constructed on the spot from materials furnished; the filter presses, small pumps, etc., were brought over from the abandoned plant. The erection of and connecting of pipes to the machinery was finished and the factory started on 29th January 1902. There were no hitches or accidents, and the factory has been in operation steadily ever since, as will be shown in the tabulated results.

OPERATION.

Process of Manufacture.—The first step in the process of manufacturing raw-cane sugar is the crushing of the cane. This cane is all weighed before being discharged into the crusher conveyors; at first sight it would seem a simple matter to determine the amount of sugar present in the cane, but in reality it is most difficult, the chief trouble being in obtaining an average sample. In this factory the weight of sugar taken into it, after leaving the crushers, is what is used to determine manufacturing losses; but the control of the crushing is obtained by regulating the amount of water sprayed on the crushed cane between the mills, so that the density of the juice issuing from the last mill is kept at a constant figure, which has been found by careful experiment to ensure a certain percentage of sugar in the cane refuse ejected after the final crushing when a certain amount of moisture is present. The moisture is regulated in the last crushing by the pressure on the top roller, and is therefore readily under control by adjusting the weights on the hydraulic accumulator. The density of the last mill-juice is regulated by increasing or decreasing the amount of water sprayed on the cane, and consequently, after the degree of density of the last mill-juice requisite to reduce the sugar in the cane-refuse to the required point has been determined, the control of milling operations becomes a simple matter of routine.

In this factory the moisture in the bagasse is kept as near 45 per cent. as possible, the density of the last mill-juice is kept at a figure which varies with the percentage of solids in solution, and the amount of sugar left in the cane-refuse varies from 4·5 per cent. to 5 per cent., which is equivalent to from 92·5 per cent. to 93·5 per cent. extraction of sugar on the sugar originally in the cane depending upon its content in woody fibre and sugar. The extracted juice on leaving the mills is weighed into the clarification apparatus already described, and the weight of juice multiplied by the percentage of sugar shown by the average sample gives the weight of sugar taken into manufacture. After being reduced to syrup, it is again weighed and sampled, and the amount of

sugar taken over determined; the difference between this and the amount of sugar taken into the house constitutes the loss between these two points. The sources of this loss are as follows: mechanical losses in transit; losses in the scums and refuse thrown into the sewer (these scums are weighed and analysed before discharge, so that the loss is known); losses in the wash waters from the juice filters; and losses by destruction of sugar due to use of re-agents, such as lime, phosphoric acid, sulphurous acid, etc., and also losses by entrainment, or the carrying over the minute particles of syrup into the condenser in the evaporating apparatus. These losses, excepting that due to discharge of scums, are usually very small; should they exceed a certain small figure, the cause is at once determined and corrected.

The syrups and molasses, after having been exhausted of all the sugar obtainable, are divided into two portions, first, the marketable sugar, of which the weight and purity is known; and second, the waste molasses, which is weighed and sampled. The sugar in the waste molasses, added to the pure sugar in the sugar marketed, will not equal the sugar in the syrup; the difference is the loss in process and consists of a certain disappearance of sugar in the vacuum pans, and mechanical losses in transit of syrups and molasses from operation to operation. These losses are generally very small, but if they are large enough to attract attention it is usually found that carelessness in the operations is the cause.

The analytical work in this factory is in the hands of a chemist, who has several assistants whose duty is to collect the samples from the various processes, weigh and polarize the juices, syrups, and sugars, and do the routine work in the laboratory. The whole work is carried on under the charge of the superintendent; the men in charge of the milling department keep a regular engineer's log-book, in which are noted the daily occurrences, and a recording steam pressure-gauge notes the varying pressure of steam in the boilers. The main engine is indicated occasionally to note how the valves work, and also to note if any undue horse-power is being developed on the mills, since the power required can very readily be greatly increased by bad setting of the returner-bar in the mills. In the log book are

also noted any slight repairs that may be needed from time to time, and from these notes at the end of the crop is determined the improvements in the milling plant, if any are needed.

The sugar-boiler, with assistants, attends to the clarifying and tempering of the juice, the filtration and concentration of same to syrup and the boiling to grain; he is responsible for the quality of the marketable product. A record is kept of every boiling of syrups and molasses, and from these records, together with the results of the sampling and analytical work by the chemist, the work done in this department, as to quality and quantity of raw sugars made, is kept up to as high a standard as possible. The sugar weigher makes up an account every day of the amount of sugar bagged, shipped, and on hand.

The chemist makes up a daily report showing weight of cane ground, weight and analysis of juice taken into manufacture, analysis of scums, sugars, and molasses, and weight of final molasses discharged; he also makes up a weekly report and, at the end of the season, a final crop report.

The superintendent of the sugar-house makes up a monthly report, in which is detailed the cost of each department, the cost of materials required in the manufacture of sugar, the total sugar made, total cane ground, the cost of sugar made per 100 lbs., and cost of cane ground per ton of 2,000 lbs. (See specimen forms, pages 938 to 945.)

At the end of the crop the superintendent of the sugar-house makes up a final report which is an abstract of all the reports, giving days of operation of machinery, stoppages and causes for same; percentage of running time to total time paid for; total sugar made and cost; also a statement of all losses. In this report is included any recommendation that may have to be made regarding additions or alterations to plant, improvements to operations and such other communications as may seem to bear upon the points of reduction in cost of manufacture or reduction of losses.

Results.—The factory commenced operations on 29th January 1902, as has been already stated. Owing to a comparatively short crop—22,000 tons of sugar being the estimate previous to 1st January

1902—and a scarcity of labour, it was decided to operate only one milling plant, so that the following figures refer to the operation of one-third of the full capacity of the factory. The machinery in operation consists of:—

1 Crushing plant, and one set of elevators and conveyors for bagasse.
6 Boilers.
1 Set clarifiers and sand filters and 8 filter presses for scums.
1 Evaporating apparatus.
4 Vacuum pans worked at half speed.
12 Crystallizing tanks of the Bock system.
16 Centrifugal machines.

The adjustments of the three mills and their returner bars took some little time; the final results are shown in Plate 89, which gives the various openings of the mills in the train, and the position of the bars, also the average power developed while crushing at rated capacity:—

Total cane ground on day of trial	1,148 tons.
Total hours run	22 hours 50 minutes.
Cane ground per hour	50·28 tons.
Revolutions of engine per minute	48.
Moisture in bagasse	45·3 per cent.
Extraction of sugar on that in cane	93·4 per cent.
Density of first mill juice solids in solutions	20·8 per cent.
Density of last mill juice solids in solution	12·3 per cent.
Maceration water added to cane between the mills, per 100 gallons of original juice	18·1 gallons.
Average power developed by engine driving mills, crusher, cane carrier, and bagasse elevator	320 H.P.

The horse-power as shown is very much below the power usually developed in crushing plants of this capacity, which is from 400 to 450 H.P., and even reaching in extreme cases as high as 600 H.P.

The comparatively small power required on this particular plant is due, first, to driving the whole of the machinery connected with the crushing and conveying of cane by one engine, thus doing away with internal engine friction; and secondly, to the form of the rubbing surface on the returner bars, and extreme care in setting these bars parallel to, and the proper distance down from the top rollers of the various mills.

The analysis of the bagasse discharged by the last mill showed a water content of 45 per cent., this being taken at the jaws of the mill, and since the water sprayed on the cane has a temperature of 170° F. the bagasse is ejected very warm; being in a very finely divided state, it rapidly loses its heat and a proportion of its moisture on its way to the furnaces, the moisture in the bagasse entering the furnaces being only four-fifths of that leaving the last mill.* The bagasse produced during the day's run was 280 tons, which lost on its way to the furnaces 20 per cent. of its moisture; the weight reaching the furnaces being 255 tons, of which 30 tons was surplus*; the remainder (225 tons) was burnt in six furnaces, each having 36 square feet of grate surface, consumption of bagasse per square foot of grate surface per hour being 87 lbs.

The total heating surface in the six boilers amounts to 15,600 square feet, and the consumption of bagasse per square foot of heating surface per hour amounts to 1·2 lbs. The high consumption of fuel per square foot of grate surface is due to strong draught, which, with the very open and fibrous nature of the bagasse, admits of an intimate contact of air with all particles of fuel, thus ensuring a very rapid and complete combustion. The ash and slag resulting from the burning of the bagasse amounts to from 1·25 per cent. to 2 per cent. of its weight, depending greatly on the amount of silica in the outer skin of the cane.

The draught pressure at the base of the chimney is $\frac{1}{16}$-inch of water, measured by an ordinary draught gauge, and the temperature in the uptake from the boilers is 540° F., taken with an immersion pyrometer. No means exists here for obtaining the temperature of combustion in the furnaces, but judging from appearances it must be approximately about 2,200° F.

---

* The following additional information was received from the author after the Paper had been read and discussed:—"The bagasse produced during the day's run was 280 tons, containing 45 per cent. or 126 tons of moisture (water), the remaining 154 tons consisting of woody fibre, pure sugar, and soluble solids not sugar. Of the 126 tons of moisture, 20 per cent., or 25·2 tons, were dissipated into the surrounding atmosphere, the weight of bagasse reaching the furnaces being (say) 225 tons, of which 30 tons was surplus," etc., etc.

Number of days grinding up to and including 30th April 1902	70 days.
Number of hours grinding in this period	1,559⅓ hours.
Percentage of grinding time to total operating time paid for .	92·8 per cent.
Cane ground up to 30th April 1902	66,672 tons.
Cane per hour average	42·7 tons.
,, ,, ,, maximum	56 tons.
Cane per day average	952 tons.
,, ,, ,, maximum	1,243 tons.
Average yield of commercial sugar per 100 of cane to date .	13·19 lbs.
Estimated sugar in cane per 100 lbs.	15·12 lbs.
Average purity of commercial sugar	96·0 per cent.
,, ,, ,, A sugar 70 per cent. of sugar shipped .	96·5 per cent.
,, ,, ,, B ,, 30 per cent. ,, ,, ,, . .	95 per cent.
Total commercial sugar made to date	8,785 tons.
Cane to make one ton of commercial sugar	7·59 tons.
Recovery of pure sugar from that taken into manufacture :—	
Pure sugar in sugar marketed	91·3 per cent.
Losses in manufacture	8·7 per cent.
	100·00
Average extraction of pure sugar from that estimated to be in the cane	92·46 per cent.
Fuel used in starting factory :—	
Wood	14 cords.
Coal	33¾ tons.
Total number employed in and about factory day and night.	160 men.

Sufficient surplus bagasse is always kept stored in front of the boilers to keep up steam for three days, thus ensuring a supply of fuel in case of stoppage in the delivery of cane for any reason, so that the stock in process can be worked up and the house cleared of all high-grade sugars without the necessity of using auxiliary fuel. A large margin of bagasse is saved in excess of this surplus, and is used in conjunction with coal for keeping steam for the irrigating pumping engines of which this company has six, with an aggregate capacity of 40 million gallons of water per day to an average height of 235 feet.

The total amount of bagasse delivered to the pumping plants up to 30th April 1902 was 637 tons.

The Paper is illustrated by Plates 81 to 92, and is accompanied by an Appendix.

APPENDIX.

SUPERINTENDENT'S MONTHLY REPORT.

PUUNENE MILLS. H. C. & S. Co.

Date ______________ 19 ______________ Month.

Returns of Commercial Sugar.

	Tons.	Lbs.
Sugar bagged		
Stock in process, as per statement		
Less stock in process reported for last month . . .		
Less low goods from last crop taken into manufacture .		
Total commercial sugar due to cane ground . . .		

Total cane ground during month . . . . .

Yield of commercial sugar per 100 of cane . . .

Tons of cane per ton of commercial sugar . . . .

Total cane ground to date . . . . . .

Total sugar made to date . . . . . .

Average yield commercial sugar per 100 of cane to date .

Tons of cane per ton commercial sugar to date . . .

SUPERINTENDENT'S MONTHLY REPORT.

Date 19 Month.

Stock in Process.

	Cubic Feet = Syrup	Cubic Feet.
Juice in mill tank	,, ,, = ,, . . .	
Juice in liming tank	,, ,, = ,, . . .	
Juice in heater and settling tanks	,, ,, = ,, . . .	
Juice in sand filters and tank	,, ,, = ,, . .	
In transit evaporator	,, ,, = ,, . . .	
In transit filter presses	,, ,, = ,, . . .	
In syrup tanks	,, ,, = ,, . . .	
Total syrup on hand		

	Lbs. Sugar.
At lbs. commercial sugar per cubic foot	
No. 1 Molasses, c. ft. @ lbs. per c. ft. . . .	
No. 2 ,, ,, ,, @ ,, ,, ,, ,, . . .	
No. 3 ,, ,, ,, @ ,, ,, ,, ,, . . .	
In mixer No. 1 sugar estimated	
,, ,, No. 2 ,, ,, ...	
,, ,, No. 3 ,, ,, ...	
No. 1 Pan in process, sugar estimated	
No. 2 ,, ,, ,, ,, ,, ...	
No. 3 ,, ,, ,, ,, ,, ...	
No. 4 ,, ,, ,, ,, ,, ...	
Crystallizers in process, at tons each	
Low goods on floor, bags at lbs. each	
Total stock in process	

SUPERINTENDENT'S MONTHLY REPORT

Grinding Department.

Class.		Days worked.	Rate per month.	Value of work.	Cost of Section.
Skilled men	1st Engineer . .				
	2nd Engineer . .				
Handling Cane	Cane weighers . .				
	Teamsters . . .				
	Animals				
	Unloading machine				
	Handling cars . .				
	Cane carriers . .				
	Car cleaners . .				
	Overseers . . .				
Grinding	Engine tenders . .				
	Cane feeders . .				
	Mill tenders . .				
	Oilers				
	Drivers				
Steam	Water tenders . .				
	Firemen				
	Ashmen				
	Carrier oilers . .				
	Extras				
Electric Light	Engine & wire men				
	Night runner . .				
Boiling House	Pump tenders . .				
	Centrifugal tender .				
Night Watchman					
Sunday Watchman					

SUPERINTENDENT'S MONTHLY REPORT.

Boiling Department.

Class.		Days worked.	Rate per month.	Value of work.	Cost of Section.
Skilled men	Sugar boiler . .				
	1st Assistant . .				
	2nd Assistant . .				
	Chemist				
	Samplers . . .				
Clarification	Superheater . .				
	Liming tanks . .				
	Filter press tanks .				
Filtration	Sand filters . . .				
	Filter presses . .				
	Repairs, filter cloth				
Concentration and Graining	Evaporator tenders				
	Pan men . . .				
	Crystallizer men .				
	Centrifugals . .				
	Molasses . . .				
Bagging Sugar	Overseers . . .				
	Sugar weighers .				
	Bag handlers . .				
	Bag sewers . . .				
	Bag markers . .				

SUPERINTENDENT'S MONTHLY REPORT.

Abstract.

		Cost of Section.	Cost of Department.	
MILLING DEPARTMENT	Skilled men . .			
	Handling cane . .			
	Grinding . .			
	Steam . . .			
	Electric light . .			
	Boiling . . .			
	Extras . . .			
BOILING DEPARTMENT.	Skilled men . .			
	Clarification . .			
	Filtration . .			
	Concentration and Graining .			
	Bagging sugar . .			
	Auxiliary fuel			
	Lime barrels			
	Filter cloth			
	Sundry stores			
	Repairs Machine shop . . .			
	Blacksmith shop . .			
	Carpenter shop . .			
	Total cost of manufacture for month . .			

Lbs. of sugar made @ per 100 lbs.

Tons of cane ground @ per ton.

ENGINEER'S LOG BOOK.

Puunene Mills.

Date ______________ 19 ______________ day

Average steam pressure

„ back pressure

Revolutions by counter :—

No. 1 mill	day	
„ „	night	total
No. 2 mill	day	
„ „	night	total
No. 3 mill	day	
„ „	night	total

Hydraulic pressure on mills :—

No. 1 mill No. 2 mill No. 3 mill

Density of juice at third mill :—

No. 1 mill No. 2 mill No. 3 mill

Time run :—

No. 1 mill No. 2 mill No. 3 mill

Tons of cane ground :—

No. 1 mill No. 2 mill No. 3 mill

Remarks

DAILY MILL REPORT.

PUUNENE MILLS.

Date ________ 19 ________ day.

Hours grinding
Hours previously reported
Total to date

Tons of cane ground
Previously reported
Total to date

Mixed juice-Brix
Pol.
Purity
Lbs. of juice into house
Previously reported
Total to date

Sugar in juice, pounds
Previously reported
Total to date

Bagasse—Moisture
Sugar
Sugar in Bagasse, pounds
Previously reported
Total to date

Syrup delivered, pounds
Previously reported
Total to date

Sugar in syrup, pounds
Previously reported
Total to date

"A" sugar made, pounds
Previously reported
Total to date

"B" sugar made, pounds
Previously reported
Total to date

1st Molasses, Brix
Pol.
Purity
2nd Molasses, Brix
Pol.
Purity
3rd Molasses, Brix
Pol.
Purity
Waste Molasses, Pol.
Purity
Polarization, "A" sugar
" "B" sugar
" Crystallizer sugar
Recovery on massecuite in percentages
"A" sugar
"B" sugar
Crystallizer sugar
Sugar in F.P. scums, pounds
Previously reported
Total to date

Waste molasses
Pounds discharged
Previously reported
Total to date

Sugar in waste molasses
Previously reported
Total to date

________, *Chemist.*

DAILY SUGAR REPORT.

PUUNENE MILLS. H. C. & S. Co.

Date ________________ 19 ________________ day.

SUGAR MADE.			SUGAR ON HAND.			SUGAR SHIPPED.		
Class.	Lot.	Sacks.	Class.	Lot.	Sacks.	Class.	Lot.	Sacks.
TOTAL			TOTAL			TOTAL		

Sugar made this day.

"A" sugar	Sacks	Pounds	Tons
"B" ,,	Sacks	Pounds	Tons
TOTAL	Sacks	Pounds	Tons

________________, *Sugar Weigher.*

CROP REPORT.

CROP 1902. PUUNENE MILLS. H. C. & S. Co.

MAUI, HAWAIIAN ISLANDS.

Crop commenced 10 a.m., January 29, 1902.
Crop finished, 9.55 p.m., November 29, 1902.
Total cane ground, 194,754 tons.
Total commercial sugar made from this cane, 25,117 tons.
Cane per ton sugar, 7·75 tons.
Total time of grinding, 4,312½ hours.
Cane ground per hour, 45·16 tons.
Juice (dilute) per 2,000 lbs. cane, 1,830 lbs.
Dilute juice, 17·64 per cent. brix = total soluble solids.
„ „ 15·26 per cent. polarization.
„ „ 86·5 quotient of purity.
Dilution, 15·08 gallons per 100 gallons of original juice.
Fibre in cane, 11·33 per cent.
Waste molasses, 89·46 per cent. brix.
„ „ 35·28 per cent. polarization.
„ „ 39·42 quotient of purity.
Average polarizations, "A" sugar, 96·97 per cent.
„ „ "B" „ 95·06 „ „
General average, "A" and "B" sugar, 96·75 per cent.
Losses in manufacture:—

In crushing and extraction .	8·37	per cent.
Between mills and vacuum pans	1·58	„ „
In waste molasses . . .	6·90	„ „
Not specially accounted for .	1·27	„ „
	18·12	„ „
Pure sugar in sugar marketed .	81·88	
Total pure sugar in cane ground . . .	100·00	per cent.

NOTE.—The reason that the nett results of manufacture for the whole crop are not as good as those for the first three months of grinding, as previously detailed, is because during the latter part of the crop the cane was deteriorating very rapidly, and quick milling could not be resorted to, as the bulk of the labourers on the plantation were engaged in planting for the crop of 1904, which contingency was brought about by the crop exceeding the estimates at the commencement of the grinding by over 3,000 tons of sugar.

J. N. S. WILLIAMS,
Chief Engineer and Mill Superintendent, H. C. & S. Co.

Discussion.

The President said the members were indebted to Mr. Williams for a very plain, straightforward account of a thoroughly modern plant. The Paper was not only very interesting in itself, but was one which would be of great value for future reference. He asked the members to accord a hearty vote of thanks to the author for the trouble he had taken in its preparation.

Mr. Andrew Brown said that had the author been present he would have liked to ask him what was the area of ground under cultivation, because, in order to keep the plant described in the Paper going at the rate of 3,600 tons per day, five or six square miles of territory would be required per month; and if the factory worked for six months of the year some idea would be gained of the immense quantity of land which had been given to them.

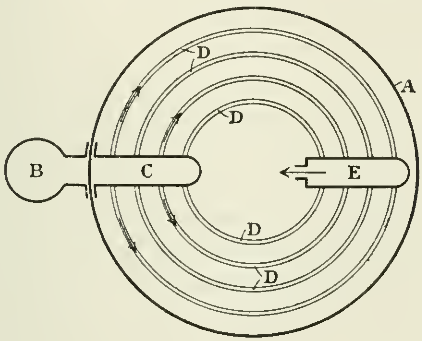
It was said (page 920) that the juice from the settling tanks was passed through sand filters. That immediately raised the question as to the quality of sugar produced. Was it a yellow class of sugar, which was known as pure Demerara, or was it of a dull greyish colour not approaching in whiteness or brightness a highly refined sugar? He asked the questions, because the sand filters were introduced in comparison to the practice in this country of using animal charcoal filters. The animal charcoal filters were usually from 16 to 20 feet deep, and the liquor which entered at the top passed directly from the top to the bottom. The result was that the sugar was brought into intimate contact with the grains of charcoal, and an excellent filtration took place; every chemical impurity and all colouring matter were extracted. He gathered from the description of the sand filters that they had an internal tube down the centre; and it struck him that the liquor must, in passing from the top, immediately seek the line of least resistance, which would be a diagonal line from the circumference of the filter towards the centre, and pass down the centre tube of the filter without having sufficient contact, such as was given in the charcoal filters.

(Mr. Andrew Brown.)

In regard to the evaporating apparatus, the author mentioned that the steam given off from the thin juice of the first body was used in the second body to evaporate further the slightly thickened juice coming over from the first body, and so on to the fourth body. It would be found however (page 921) that the author said, "The juice under operation showers down over the heating surface in a spray, the steam being inside the tubes." It was important to remember that the action of an evaporator of that kind was very much on the same lines as a quadruple-expansion engine. In the first cylinder there was a high temperature, and as the action took place from No. 1, No. 2, No. 3, and No. 4, the boiling temperature of the liquor was reduced and the vacuum increased. Therefore the temperature of evaporation in the No. 4 was lower than the temperature of evaporation in No. 1, and, as was explained in the Paper, the vapour which was given off in No. 1 being slightly hotter than the juice in No. 2 and No. 3, each quantity of vapour had the power of evaporating still further the cooler juice which was in No. 2 and No. 3. He thought the author had made a mistake at the bottom of the page (920); he said that "the juice containing some 16 per cent. of solid matter in solution enters the apparatus, and is discharged containing some 60 per cent. of solid matter, having lost in the operation about 75 per cent. of the water originally contained in the juice." Up to that point the author was quite right, but he thought an error had crept into the next sentence, where he said, "This water, which is delivered by the evaporating apparatus in a pure state, is used for feed make-up for the boilers." The whole process of evaporation by the aid of a vacuum had a tendency to draw off the small particles of the sugar along with the vapour, passing directly into the condenser where it met the injection water, the whole of the injection water and the condensed vapour immediately passing over to the drains. Consequently he thought the water mentioned was really intended to be the condensed water which was passing through the tubes in the form of steam at 5 lbs. pressure; and it was that condensed water which was taken away and used again in the boilers.

The vacuum pan was stated (page 921) to be 10 feet 6 inches in diameter and 15 feet deep. He ventured to say that the design of the pan was not a very favourable one. The practice was to have a larger diameter but a shallower pan, so that the action of the liquor during evaporation was rapid and not retarded and slow, as it must be in a pan of the depth described. The coil was stated to be 1,000 superficial feet of 2 inches diameter. It was to be understood from that statement that the coil must be 2,000 feet in length. It was divided into sixteen separate coils, making sixteen separate coils of 125 feet. There again he thought the practice was wrong. Amongst engineers in this country it was the practice to make vacuum pans with heating surface coils of not less than 4 inches

FIG. 13.—*Vacuum Coil arranged for getting rid of Condensed Water.*



diameter, the tendency being to make the coils as short as convenient, so that the condensed water which formed while the coil was doing its work could be got rid of. By that means the heating surface was heated with steam and was not sagged, as it were, with a load of condensed water near the bottom of the coil. The heating surface given in the Paper measured out to about 2 superficial feet of heating surface to 1 cubic foot of capacity in the pan. The usual practice in this country was $1\frac{1}{2}$ feet of superficial area to 1 cubic foot of capacity in the pan. This helped to demonstrate the inefficiency of the small coil, which was very long, as there was a portion of the coil which really had not much effect. He

(Mr. Andrew Brown.)

illustrated, by a sketch, Fig. 13 (page 949), a system which was used with the idea of getting rid of the condensed water in a vacuum coil.

The circle A of the diagram was the diameter of a pan. The arrangement he referred to was, that the steam passing through the valve B would enter into the common box C on one side of the pan. The lines D represented the steam coils. There were usually six from the circumference of the pan towards the centre, and four or six superimposed one on the other. The steam entered into the common box C, and immediately found its way in both directions round the circumference, and on meeting in the box E the condensed water from the steam was immediately drained off by the steam-trap at the bottom of the pan. By that system it was always possible to have a live steam heating surface presented to the liquor in the vacuum pan.

In connection with the centrifugal machine (page 922), he thought that the speed mentioned of 1,000 revolutions for a 40-inch centrifugal was rather high. The usual practice in this country was to have a speed not exceeding a periphery speed of 8,000 feet per minute, whereas it amounted in the Paper to 10,000 feet. He would like to ask the author whether the centrifugal baskets had been specially designed to be extra strong for that purpose, or whether a little more was being risked with less margin of safety. It was stated (page 922) that the machines were driven by water pressure, and an air-cushion was introduced which had the effect of steadying the pressure. That was quite likely, but he thought perhaps it was unnecessary. It was quite common in this country for the Weston centrifugal machines to be driven continuously at a water-pressure of 160 or 170 lbs. without the introduction of an air-cushion, but why the air-cushion should be 60 feet high he could scarcely imagine. The pressure by the volume equalled the constant, and why the column of air should be so very long he could not understand. It would be most interesting if the author would state what was the diameter of the air-column.

He would also like to say a few words with reference to the sugar crystallised from the No. 3 molasses, which to those who were not acquainted with the crystallisation of sugar perhaps might

seem absurd. It was stated (page 924) that the resulting sugar, which was of too low a grade to ship, was drawn into the vacuum pan while boiling No. 1 sugar, and was thus converted into No. 1 sugar. They were dealing with the liquor from which there had been grained a quality of sugar from a No. 3 molasses, that is, the first sugar had been drawn off, the first molasses had been boiled, No. 2 sugar had been produced. No. 2 molasses had again been boiled, and No. 3 sugar, which was of a very low quality, was then arrived at. He wished to say, however, with regard to the quality of that sugar that, although it was very poor to look at, the small grain formed in the crystallizers was practically a pure sugar, but having been in contact with such very poor molasses it was altogether coated round with something very sticky and gluey. Therefore, when drawn into the pan along with No. 1 sugar, the first action of the pan was to wash off all the glutinous substance which adhered to the grain, and when thoroughly washed off the skilful pansman would build on the top of the little core the larger grain which was required for commercial purposes.

The author stated (page 936) that the bagasse produced during the day's run was 280 tons, 30 tons of which were sent into the store and 25 tons of moisture was lost in evaporation. He would like to ask the author to qualify that statement, and make quite sure that it was right. It seemed to him extraordinary that 25 tons should evaporate during the time it took for the bagasse to travel from the last crushing roller up to the boilers. It must also be remembered that the factory was only running at one-third of its power, and when one came to think that 75 tons in a 24-hours day at full load would be evaporated, it amounted to something like 3 tons an hour; and as the time taken in travelling from the last roller up to the boiler could not exceed about three minutes (taking the travelling at the rate of 50 or 60 feet per minute), the quantity of evaporation which must take place in that very short journey was equal to at least 3 cwts. of water evaporated. He thought there was some mistake on that point.

In conclusion he wished to draw attention to a statement (page 912), which was the crux of the whole of the commercial life,

(Mr. Andrew Brown.)

namely, the reduction in the margin of profit. The author stated that twenty years ago the average yield of commercial sugar was 9 lbs. per 100 lbs. of cane, and the average yield of cane per acre was about 25 tons; now they were able to produce sugar cane of 12 per cent. with 40 tons per acre, which showed that as far as agricultural considerations were concerned the total output from the plantation had been increased by something like 80 per cent., which was a very commendable increase indeed. But, unfortunately, the author, although he spoke of a margin of profit, did not give the slightest inkling as to what the cost of the cane and the commercial value of the sugar produced twenty years ago were, and what they were now. He would like the author to give some information if possible as to the two conditions prevailing, that is, the cost of the cane and the commercial value of the sugar produced in 1882, and the cost of the cane at the rollers and the commercial value of the sugar sold in 1902. In this country for the past fifteen years the sugar refiners had been face to face with an enormous reduction in the margin of profit. In 1882, the difference in value between the raw imported sugars into this country, and the selling cost of the sugars produced, was something like £10 per ton; but today, what with the serious reductions which had taken place on account of the bounty-fed system, and, during the last two years, the further addition which had been added to the cost of raw sugar by the introduction of the import duty, the difference in value was now reduced to something near £5 per ton. He thought it was to the credit of every manufacturer and refiner in this country who had succeeded in keeping their works open, and going ahead as they had done, in spite of the terrible reduction of at least 50 per cent. in the margin of profit. It was not at those refiners that the people of England could look askance and say they had been asleep. For some time back they had been told as engineers that both their German and American friends were simply leading them, but he thought the refiners of this country were entitled to credit for the way in which they had been able to hold up their heads, and had sufficiently fortified themselves against the enormous reduction in the margin of profit which was likely to take place. The amount of depreciation

written off in a sugar refinery and the amount of money spent in improving the plant year by year, week in and week out, could hardly be imagined. There was always something fresh being done; and it allowed them to place on record the fact that they were still able to meet their foreign competitors and carry on an enterprising trade in this country.

Mr. W. Price Abell said it was very appropriate that the author had introduced his most interesting Paper at a time when the baneful effects of the unjust Continental bounties were on the point of being done away with. He was, however, sorry that the magnificent factory described by him was not on English ground as it might have been, had it not been for the ruin caused by the bounties. It was a further illustration of the care taken by their neighbours of their own Colonial industries.

He noticed that the author gave the yield of commercial sugar at about 12 lbs. per 100 lbs. of cane, in fact later on in the tabulated returns he gave 13 lbs. This was remarkable, but was not entirely due to the perfection of the manufacture; in fact, a very great part was due to the cultivation resulting from the very favourable conditions under the irrigation system they had in Hawaii. For the building they were fortunate in having stone foundations, allowing a load of 3 tons to the square foot, whereas in Demerara it was impossible to allow more than half-a-ton to the square foot, and this applied to soft ground in general. The unloader adopted by the factory described in the Paper was far in advance of anything he (Mr. Abell) had seen, in fact it appeared to get over practically what had hitherto been an almost insurmountable difficulty. As they knew, many schemes had been devised, the speaker well remembered seeing a most elaborate apparatus for lifting a truck or punt bodily and emptying the same into the bagasse carrier.

Engineers would take decided exception to the boilers used in this factory. They were given as 20 feet long having 4-inch tubes. Now, from the speaker's experience in Demerara, the practice of making the length of the tubes 40 times the diameter was found the most efficient. This resulted in boilers averaging 12 feet long. As

(Mr. W. Price Abell.)
engineers recognised that the first 3 feet of heating surface in a tubular boiler practically did all the work, this abnormal length of 20 feet would somewhat throttle the draught, and would have been far more effectively utilised if divided into two boilers. Then with regard to the reduction in the width of the fire-grates by building up underneath the fire-bars, the speaker's experience very distinctly pointed that they would have made them considerably more efficient had they continued building up through the grate, the hot bricks through radiation and contact playing a necessary part to efficient combustion of bagasse or megass. The speaker quite recognised the difficulty of doing this, and met the same, with step grates some few years since.

The juice strainer described would certainly not be so efficient as the revolving perforated vat used on some Demerara estates. This vat was keyed on to the top roll shaft and was of sufficient diameter to receive the juice discharged from the mill, the cushcush being carried round in this towards the top from whence it fell off on to the shoot, discharging it again into the mill while the liquor found its way through the perforated sides. This arrangement was absolutely automatic, self-cleaning, and remarkably simple. The evaporating apparatus, giving 5 lbs. per square foot of heating surface in the four bodies, was remarkably good, and was somewhat explained by the fact that the heating surface was new and consequently clean.

The author's statement, that 3 tons of bagasse containing 45 per cent. of the moisture was considered equal to 1 ton of ordinary Australian coal, was interesting when compared with the equivalent of Egyptian sun-dried bagasse which Dr. Letheby found took 2·09 tons to be equal to 1 ton of coal; one corroborated the other, the fact that one was sun-dried and the other green would easily account for the difference. Further it was interesting to note that they utilised molasses as fuel, and that its calorific value was equal to that of megass or one-third that of coal, and considering that they had at Maui 60 to 200 gallons per hour of this molasses, or taking an average of 1,300 lbs. running into say 12 tons per day, they had on the whole grinding of 70 days a considerable addition to fuel,

equivalent to 840 tons of megass. It was interesting to note that 20 per cent. of diffusion water was added to the megass, and that this amount was re-evaporated from the megass on its way to the furnaces. This seemed rather a large amount, but under continual movement in a hot atmosphere it was quite possible.

Looking at the analysis of work during the first grinding, one was struck with the percentage of grinding time to total operating time paid for being 92·8 per cent., a fact which unmistakably pointed to splendid engineering organisation and skill having been carried out during the whole of the erection, for, as everyone knew, the first running of a vast set of new machinery as assembled in the Maui factory would, on the slightest bad workmanship in any part requiring attention, have necessitated the stoppage of the whole factory. One was also struck with the good return of 13·19 pounds of commercial sugar per 100 pounds of cane. As the result of working, it was interesting to note that the amount of megass derived from the crushed cane, after running the factory, left a surplus of 637 tons for use at the pumping plant. Now this at first sight appeared all that could be desired, but when it was remembered that at Maui they did not utilise molasses for making rum, involving the use of considerable extra fuel, as was done in the sugar estates in the West Indies, and particularly in the efficient factories of Demerara, one was persuaded to think this fuel question deserved attention; in fact the speaker knew several estates in Demerara where even eight or nine years ago far better fuel results were obtained from very much older machinery, lower boiler pressure, with only day work, instead of continuous running, than was obtained at Maui. This was proved by the following extract from a Paper read by the speaker before the Institution of Civil Engineers * :—

"The results of long grinding at a factory producing $1\frac{1}{4}$ tons of sugar per hour show that the amount of megass available per hour is 3·75 tons, consisting of 2·03 tons of fibre and 1·72 tons of water. This is burnt in five furnaces, 4·24 cubic feet of megass being thus

* Proceedings, Inst. of Civil Engineers, vol. cxxiii, 1895–96. Part I., page 370.

(Mr. W. Price Abell.)

available for each furnace per minute; but sufficient steam is maintained with 3 cubic feet per minute. Each furnace has a grate-area of 20 square feet, and each supplies heat to a multitubular boiler containing 1,300 square feet of heating surface. The chimney draught, as shown by a Bailey draught-gauge, is 40 feet per second, the flue temperature, as shown by a Bailey pyrometer, is 500° F., and the furnace temperature is such as to melt copper and partially melt cast-iron, about 2,000° F. In addition to extracting juice from the canes with a pressure of 250 tons on each of the top rolls, the water is evaporated, the sugar is cured, and the molasses is converted into rum and second sugar. The 3·75 tons of megass develop the requisite power without the assistance of any other fuel, the duty of the engines employed amounting to 463 I.H.P. and the heating surface in the evaporators being 5,650 square feet." At this factory very little diffusion water was added, but what more than counteracted this was the fact that the factory did not work the 24 hours through, and consequently every night a considerable cooling down of furnaces and heating apparatus took place and considerable fuel was required to get everything started afresh in the morning; whereas at Maui they ran continuously for 24 hours, the amount of rum made at the former factory varying between 30 and 40 gallons per ton of sugar. Taking these results into consideration, and they were not isolated, it appeared to the speaker that with more efficient furnaces at Maui, instead of having a surplus of 637 tons of megass to their 70 days' grinding, they ought to have had twice that amount, plus the equivalent of molasses used for fuel, which, as previously stated from the data given, amounted to 840 tons, giving in all a total of over 2,000 tons of surplus megass for use at their pumping engines. It would be invidious to say more in regard to furnaces at this juncture.

The factory was doubtless a very fine specimen of centralisation, but in this case particularly the question arose how far it paid to centralise, and at what point was the acme of commercial economy reached. As pointed out by Mr. Brown (page 947) this enormous factory required canes grown on a very large area of land, and as all cane growers knew, the sooner the cane was in the mill after leaving

the cutlass the less the loss was from inversion; whilst from an engineering point of view there was a very definite limit to the commercial efficiency of engineering units. Whether this had been overstepped at Maui so far appeared to be interesting and open to question.

Mr. LLEWELLYN JONES said he was very pleased to have an opportunity of expressing his full appreciation of the author's interesting and instructive Paper. The British sugar colonial industry required all the assistance it could possibly obtain in the present trying times, and it was very important that its engineering requirements should be frequently brought before the notice of the mechanical engineers of the country, because it was well known that through the attention and application of many independent minds steady and continuous progress was assured. So far as the great majority of British subjects were concerned, colonial sugar machinery had been somewhat out of sight, and, therefore, out of mind. That circumstance without doubt explained why Continental and American sugar factories were more favourably situated than British colonial factories, and likewise partially explained the fact that American sugar machinery was becoming a formidable opponent to British sugar machinery in the British colonial markets. He was therefore inclined to think that the members of the Institution, and the owners in the country of sugar estates, would be very much obliged to the author for having brought the question of machinery in sugar factories before the notice of the Institution.

He presumed the Paper might chiefly be regarded as an exposition of American versus British sugar machinery, and the prominent features concerned might be said to have reference to the following points:—first, the novel method of feeding the canes into the cane mills. It would be noticed in the Paper that very special apparatus had been arranged for withdrawing the canes from the trucks on to the cane carrier. In the second place, there was a very powerful eleven-roller cane-crushing plant, which was entirely on American lines originated in America. Thirdly, there was a complete and elaborate labour-saving machinery which fed the crushed and

(Mr. Llewellyn Jones.)
exhausted canes known as megass into the boiler furnaces, together with the use of molasses as auxiliary fuel. In the next place, there was what was to him the very unexpected employment of multitubular boilers of unusual and excessive length, which he regarded as one of the weakest and most objectionable points in the entire installation. That point had already been brought to the notice of the members by Mr. Abell (page 953). In the next place, there was the application of high temperature and high static pressures in the clarification of the cane juice, together with the use of sand as a filtering medium. He was very much surprised at this employment of sand. He should have thought it would have been liable to cause a considerable amount of acidity, and consequent loss of sugar, and, as was known, sand had not the absorbent properties of the charcoal which Mr. Brown had explained (page 947). He would be very glad if the author would give a few more particulars in regard to the sand filters. In the next place, there was the employment of the Lillie film evaporator, which was a special form of American evaporator.

The last point which had attracted his attention as an engineer was the electrically-driven centrifugal machines in place of water-driven and belt-driven machines. Necessarily his remarks must be very brief. In the first place, he wished to ask the author to explain specially and carefully the precise details of the application of the water which was sprinkled on to the megass between the first and second and third sets of rolls. That point had to be carefully arranged in order to secure the best results; if it was not done in exactly the right manner, and very carefully regulated, an excessive and unnecessary dilution was obtained, which meant a consequent increase in the consumption of fuel and extra work without any corresponding advantages.

He next wished to mention that the author fully confirmed his own experiments and expectations with regard to the use of molasses as an auxiliary source of fuel. Molasses had latterly been a drug upon the market, and therefore it was most important to institute any methods likely to enhance the value of such an abundant by-product of sugar-making. In that connection he wished specially to mention that Mr. George Hughes, of London,

had recently taken out a patent for mixing finely-powdered megass with molasses. Fine megass possessed the somewhat unexpected and extraordinary property of being easily able to absorb four times its weight of molasses, and, subsequently, with very little drying, it formed an excellent food for cattle, for which there appeared to be a large market. That novel process opened the door to the employment of a class of machinery made in this country which hitherto had not been used on sugar estates. He had brought with him to the Meeting a sample of the crushed finely-powdered megass, which might be inspected by the members. It possessed 75 per cent. of nutritive matter; 75 per cent. was digestible. It was also well known that molasses was a very digestible substance, being even more digestible than crystallisable sugar; medical men would give treacle to an invalid when they would not give sugar. The megass almost immediately absorbed the molasses, and formed a very fine sample of cattle food. His friend Mr. Hughes was always reminding him of this percentage of nutritive matter in the megass, and that 75 per cent. of the interior cellulose fibres of the sugar-cane, that originally held the juice, were digestible and therefore of good food value. Bulwer Lytton had said, "The worst thing you can do with a man is to hang him," and his friend Mr. Hughes similarly said the worst thing one could do with molasses was to burn it; it should be made into cattle food.

In conclusion he wished to deal with a rather difficult point which had reference to the way in which hydraulic pressure was applied to the rolls of the cane-crushing plant. On Plate 89 some diagrams were given, the author stating that the hydraulic pressure was applied to the top roller of each set of rolls in the large mill. It was really what might be called a 9-roller plant with two preliminary rollers for the first squeeze. The first set comprised three rollers, the second set three, and the third set three, making up the nine. In the three cases mentioned the hydraulic pressure was applied to the top rollers. The arrangement with regard to the first set of rollers might be allowed to pass without much criticism; and possibly it might be considered almost hypercritical to object to the same arrangement on the second set of rollers; but coming to

(Mr. Llewellyn Jones.)

the third set—the final squeeze—he felt very strongly that the pressure should be applied to the bottom left-hand roller in the diagram. He had always advocated the application of hydraulic pressure to the back roller in preference to the top roller; without any hesitation he went so far as to say that it was a very great mistake to apply hydraulic pressure to the top roller of any cane or megass mill, especially a megass mill, save as a safeguard against breakage due to undue strain. The hydraulic pressure could be put on the top roller. It should then be loaded to the fullest extent, with due regard to the safety of the mill, so that the top roller might be practically stationary; a lesser hydraulic pressure could then be applied to the back roller, which was intended to ensure the final squeezing. If the members examined the diagram, Plate 89, they would understand that the trash-turner bar, which was called in the diagram the returner bar, was a solid fixture, and very strong. The canes were fed in through the first two rollers in each case, and passed over this bar, and in order to drag them across the dead surface such an amount of pressure was requisite that they almost formed into the consistency, for the time being, of a green wood plank. When an accident had happened, when a roll-gudgeon had suddenly broken and the roll had had to be lifted out, although the roller was pretty well got out of the way and the megass was lying on the top of the returner bar, it was necessary to take a crowbar to remove it, and even then it was very hard work. It would therefore be seen that that hard substance passing over the top of the returner bar must tend to lift the top roller, and if the hydraulic pressure was not sufficient to withstand that pressure it lifted it away from the back roller. In the arrangement shown in the Paper, the back roller had no hydraulic appliance added to it, it remained stationary. The gap between the two rollers which were intended to give a final and thoroughly efficient squeeze was unduly increased, and the megass escaped scot free, so to speak; and although it looked in appearance very much more crushed, much more finely pulverised, all the work had been done in the wrong place. It had been done between the trash-turner bar and the top roller, instead of between the two rolls, and the megass was

moister than it ought to be. He knew that from practical experience, as he had gone very carefully into the point; in fact he considered he had worked it out almost to an absurdity. He found in the case of a single mill that, in spite of the application of the maximum amount of fully 3 tons hydraulic pressure per square inch on the rams of the top roller, 63 per cent. moisture was obtained with 60 per cent. increase in normal engine power, and with 2½ times the normal hydraulic pressure; whereas an efficiency of not more than 56 per cent. of moisture was obtained against 63, with a very moderate and suitable pressure on the back roller and without undue increase of engine power. The points he had mentioned seemed to him to be the prominent ones in connection with the Paper. He did not pretend to have dealt with everything which had attracted his attention; but the last question he had mentioned in regard to the application of hydraulic pressure was one which every engineer present would clearly understand and take an interest in.

Mr. David Martineau said that as an old sugar-refiner with fifty years' experience, he would be pleased to say a few words in connection with the very interesting Paper upon the manufacture of sugar in its early stages. His experience in that direction had been gained chiefly as a sugar-refiner in England, backed up by studying the matter as a visitor in the best and largest beetroot factories on the Continent, and also throughout the West Indies and Demerara. His experience in that respect was gained thirty years ago, and thirty years ago of course was not the same as at the present time. He was astonished at the enormous size of the plant described in the Paper, and the distance the sugar-cane would have to be brought from the fields to the mill. Although railways had been laid down on the plantation, it was found that one very quickly came to the limit in which it was possible to work profitably a sugar-cane or beetroot before it deteriorated. The Hawaiian Islands were on the same latitude as Jamaica, or thereabouts; the one was in the Atlantic and the other in the Pacific, but he did not apprehend that that would make much difference in the temperature, which was the

(Mr. David Martineau.)
great point which regulated the rapid fermentation or acidification of the cane. The cane when it was cut had a good deal of juice dripping out from it, and if that was left in the sun only for a few minutes it would begin to ferment and turn into something of a very inferior quality. He had seen in a mill, driven in the very crude and old-fashioned way with a windmill, with the rollers upright, the juice extracted from the cane run down an open trough, perhaps 30, 40, or 50 yards long, to the iron pans where it was boiled, and before it reached the pans it was in a violent state of fermentation. In reading the description of the mills given in the Paper, he noticed that no mention was made of a hot bed, which was very common in Demerara, so that the juice, directly it was extracted from the cane, began to be heated, which enabled it the better to resist the action of the atmosphere. The process mentioned in the Paper was open to very serious objections. In the first place, the "messing" of the juice about before being boiled must be very detrimental to it; and that messing was also continued in the very curious process of filtering through sand. He thoroughly endorsed the remarks of previous speakers on that point; he did not believe filtering through sand was anything approaching as valuable as filtering through charcoal. He could understand the assertion that charcoal was an expensive and rather wasteful process, because it must be remembered that the climate was a hot one. The sweet water obtained from charcoal when it was washed out was very liable to turn sour, and directly it turned sour it made molasses and not sugar. The same remark applied to the sand, and he apprehended that a very great deal of fermentation must take place in the frequent washings required from the sand.

Mr. Brown had already touched on the point (page 951) he had intended to enforce, namely, the tiny atoms of crystals which were to be found after the boiling, or during the boiling, of the very low grade second syrup which made the third grade sugar. Those little crystals, as the speaker had properly pointed out, were almost as pure as the crystals obtained from the first running, but they were surrounded by such an immense quantity of gummy inferior and low grade syrup, that it must retard and injure the boiling of the No. 1

quality. It appeared to him to be quite a wrong arrangement to put the lower quality into the better one, to make the better one a little richer. It would not make it any richer. The little piece of grain had better be got out by some other process, and the syrup should be turned into something which would pay better, in connection with which several propositions had been made. In the effort to get the little bit of grain out, the quality of the best sugar was being deteriorated, because the longer sugar was boiled and kept in contact with heat the more it deteriorated in colour; it lost its colour and would gradually become caramelized or injured in its crystallizable part.

It had been already pointed out that the burning of the molasses was a very wasteful process. Mr. Llewellyn Jones had made a proposition (page 958) which struck him (Mr. Martineau) as being a more valuable mode of deriving some benefit from the molasses. In the West Indies thirty years ago a large amount of scum and such kind of sweet residues were carefully put aside into great pits with the waste waters, and were afterwards turned into rum. He had been on estates in Jamaica where at that time a better price could be obtained for the waste in the shape of rum than for the best suga made. He did not believe such a thing was a common occurrence, but it was done in certain places where they had "the turn of the hand," as it was called, or a particularly favourable old-fashioned still which would make the rum of the right quality. The process described by the author, by means of which they were able to burn the wet megass, was one of great merit and possessed very considerable economy. Thirty years ago he had been on estates where, in order to burn the wet megass, fuel in the shape of coal, wood, or bamboo had had to be added, because the quantity of moisture left in was so great that by using the megass alone the whole of the work could not be done. In Demerara large places were constructed where the megass was thrown up into the air and sun-dried, by means of which process 40 or 50 per cent. of the moisture was got rid of. He attributed the fact that they were able to burn the megass in the factory described by the author to the preliminary crushing. Before the sugar-cane went to the crushing rolls, it passed through a

(Mr. David Martineau.)

machine where the whole of the cane was macerated and broken into small pieces not more than six inches long. That was done by a machine with peculiar-shaped teeth which interlaced with one another in two rolls, which smashed the cane up so small that, after it had gone through the nine rollers, the air was able to act upon it much more quickly and to dry it. Personally he had never seen anything like a nine-roller mill, and therefore had had no experience as to what the effect would be after the material had gone through the nine rollers, but Mr. Llewellyn Jones had described the process very clearly (page 959). The author had spoken of drying 20 per cent. of the moisture out. He (Mr. Martineau) could hardly understand how it could be done as quickly as that, but there was no doubt that a hot substance, directly it got into the air, would throw off a very large quantity of vapour, which would make the megass much more burnable. The description of the various processes of the operation had been extremely interesting to him as a sugar-refiner. The statistics given were of the greatest use. He had never seen statistics of a sugar plantation kept with anything like the care which seemed to be bestowed upon those given by the author, although he had been in some of the splendidly managed and very beautifully fitted up central factories in Martinique and Guadeloupe, where, thirty years ago, the apparatus was far ahead of any sugar-refining machinery in existence, with the exception of some of the complete estates in Demerara.

Mr. CLAUDE T. BERTHON said that Mr. Llewellyn Jones had mentioned (page 959) the very great density to which the megass was brought in the space on the top of the returner bar. He wished to point out that all recent progress had been in the way of raising the trash-turner bar, which would at first sight appear to increase the pressure in the enclosed space; but the fact of the matter was, that the front grip between the front and top roll of a three-roll mill was practically the means of giving a forced feed to the back grip, and a shallow setting of the plate caused the megass to pass through without the crimping or doubling on itself which occurred with a deep setting. Some reports had been published quite recently by

the Java Agricultural Congress, where trials were described in which the trash-turner bar of a three-roller mill had been raised from $2\frac{5}{8}$ inches to $1\frac{3}{4}$ inches, with the result that the I.H.P. of the engine had almost been halved. Very considerable attention had been given in Java, and he presumed also in the mills described, to the correct curve of the plate. The author remarked (page 935) that extreme care was taken in setting the bars parallel to the top roller. As far as he knew, it had always been the practice to give the trash-turners a certain definite let off, that is, to increase the opening gradually from the front roller to the back; and it would be very interesting if the author could give some particulars of the way in which the centre, from which the curve of the trash-turner was struck, was determined for the particular mills described.

He would like to bring to the notice of the members a new departure in connection with the driving of centrifugals which had recently been made, in fact which had barely got beyond the experimental stages; he referred to driving by electricity. As all engineers knew, electrical driving made it possible to determine accurately at any moment, by the observation of measuring instruments, the amount of power required for driving machines, in a way that no other means of driving could be gauged. It was a very curious thing that it had been established by trial after trial, that the same power was absorbed by a machine whether it was loaded or empty, the only difference being the increase of time required for the loaded machine to get up speed, that is, to overcome the inertia of the load. That was supposed to be on account of the main resistance to the rotation of the basket being the churning of air in the space between the basket and the outside case; the load being carried on polished steel washers was carried almost frictionless. A machine carrying 8 cwts. of sugar could be moved with one hand on the circumference of the basket. The Weston machine was mounted on flexible bearings; the motor was suspended from the flexible bearings, and was free to oscillate with the machine. The armature was mounted loose on the spindle, the motion being transmitted to the spindle by means of a friction coupling consisting of plungers shod with leather, going out under the action of

(Mr. Claude T. Berthon.)

centrifugal force against the inner rim of a cup. In that way it was possible to start the motor without any starting resistance ; it started with no load. Directly it was started the friction plungers flew out, and it began to pick up the basket and speed ; no rheostat was required to start the machine, the current being switched straight on. A machine on such lines had been working in a refinery in London for the last five or six months, and the proprietors of the refinery were so favourably impressed with it that they had ordered a plant of six machines. Another plant of six machines had also been ordered for a place in Trinidad with which he was connected as the consulting engineer. From observations of the ammeter of one of the electrical machines, it appeared that the requirements in the way of current did not become constant at the time at which the machine had reached full speed. The current continued to fall gradually during practically the whole of the run of the machine. If the machine ran after the molasses had parted from the sugar, the current became practically uniform, but until the molasses had passed out of the basket the current gradually fell. It therefore appeared that something was wanted in the driving arrangements for a water machine. As the Paper explained, the water machine was driven in the first instance by two jets to get up the speed, and as soon as the speed was up the accelerating jet was shut off. If the gradual drop in power required to sustain motion took place—and it seemed to be proved beyond doubt by the electrical observations—the jet to keep the machine at speed must, in order to sustain the speed at the beginning of the period after it had attained full speed, be sufficiently large, and, as the power required fell off, a certain amount of water was used wastefully ; it followed the wheel, and did no work.

Another point which had struck him in connection with the pumps, which were used in the installation, was the fact that duplex pumps, as most engineers knew, were the most wasteful steam-users that could be found, and therefore the actual efficiency from steam to motion in the centrifugal was certainly bound to fall very much lower in the water machine than in the electrical.

The PRESIDENT said that as Mr. Williams was not in England it would, of course, be impossible for him to reply to the discussion that evening. Reports of the remarks which had been made, and of any other written comments which might be received by the Secretary, would however be sent to the author, and his reply would be embodied in the report of the discussion as printed.

Communications.

Mr. ROBERT DUMAS wrote that it appeared from the Paper and from the remarks of several of the speakers that great efforts were now being made in raw sugar factories and in refineries to get as much sugar as possible out of the molasses in a crystalline form. It was possibly not a matter of common knowledge that at the present time large quantities of sulphate of strontium were being exported from this country to Germany to be used, after having undergone various chemical processes, for this very purpose.

When this industry was initiated, the strontium sulphate was first sent by devious routes to Germany in order to keep the suppliers in ignorance as to its destination. Much of this mystery had now vanished, and the interests of the proprietors on whose land the strontium sulphate (usually spoken of as spar) was found were being looked after in an intelligent manner. So far as the writer was aware, no use whatever has been made of the mineral in this country or in the Colonies, which seemed all the more regrettable, seeing that the spar was one of this country's natural products. The spar was found in Gloucestershire in beds up to about three feet in thickness, at depths varying from about two to twelve feet under the surface of the ground.

The writer understood that the method of using the strontium sulphate was roughly as follows:—It was first converted into a sulphide, it was next converted into a chloride and then to a carbonate. The strontium carbonate was then calcined to get strontium oxide. This strontium oxide was mixed with molasses and a strontium saccharate was formed. Carbonic-acid gas was pumped

(Mr. Robert Dumas.)

through the mixture and the strontium was brought down in the form of strontium carbonate which was again calcined, and was then ready to be used afresh. The sugar which went to form the strontium saccharate was, after the splitting up of the compound, left in a crystalline form. Samples of the spar had been sent to the Institution, and they were open to the inspection of anyone interested in the matter.

Mr. ROBERT GRAHAM, of Ponce, Porto Rico, wrote * that Mr. Andrew Brown (page 947) was quite right in saying that, to supply such a factory with canes required a large acreage, and it was now beyond a doubt to those who had had the experience in both large and small sugar properties, that, with fixed and portable railways, as were now in use on the larger sugar properties, there was less time and money lost in carrying canes 20 miles than in carrying them 1 mile on smaller properties by old methods. It was just as easy to put 3,000 tons of cane through the mill within 24 hours of cutting as it was to put 100 tons. All depended on the management and appliances.

He thought that Mr. Brown was in error regarding charcoal filters for sugar estates. No doubt these were the best for refineries where white sugars had to be made, but for sugar estates they would never do, and so far, the very best for the purpose were the sand filters. He was partly right in his criticism of the vacuum pans (page 949); 14 feet diameter would be better for pans 15 feet high, but 2-inch coils were much better than the old-fashioned 4-inch coils, and he was quite right in saying that the coils should be short. The best practice now was to have the coils nested in three or four sets, each set having its steam valve, so that there would be only three or four steam valves for the largest pans. Each coil should take one complete turn of the pan, and a large well should be left in the centre inside the short coils. There were several of these pans at work now in Hawaii and Cuba, all giving excellent results for

* This communication was received too late to be seen by the author before preparing his reply.

the owners, and being very much to the satisfaction and comfort of the pan boilers. Fig. 14, Plate 91, illustrated one of these pans.

Referring to the unloader which Mr. Abell (page 953) considered so superior to hand work, the writer thought it was far behind the unloaders at work on one of the new factories at Ponce. This factory was, at the time of writing, taking off its first crop, and had two sets of mills. There were no cane-carriers, but simply a hopper close to the first crushers, and overhead a travelling electric crane. The cars ran alongside the hopper, and two labourers ran the chains underneath the canes, thus weighing from five to six tons by hitching on to the weighing-machine hanging from the crane. Another labourer sitting on the crane hoisted and ran over the hopper, meanwhile the weigher standing by the weighing-machine over the canes weighed and took from the machine a card having the net weight printed on it, and with a touch of a lever, dropped the cane into the hopper. From the hopper the cane was raised by a short chain elevator with teeth that carried the required amount of cane and dropped it into the crusher. In this way four labourers could handle comfortably 60 tons of cane per hour. On another factory they had the same arrangement as on the Puunene factory, and the difference in economy and facility was very marked in favour of this hopper and weighing arrangement.

His experience with boilers differed from that of Mr. Abell (page 953). At Ponce they commenced fifty years ago with boilers 10 feet in length, which had gradually been increased to 16 feet, and in one case to 18 feet. Most of their boilers during the last ten years were 16 feet by 9 feet, and the results were vastly superior to the former 10-foot and 12-foot boilers. Now that, by the use of pneumatic tools, boilers could be riveted up on the estates, he believed that the most economical boiler in every way for colonial sugar estates would be 20 feet by 9 feet, and that such a boiler would give more steam with the same amount of fuel as two 12-foot boilers. The writer had had similar experience to Mr. Abell with furnaces; he had built up the sides so as to reduce the grate area from 36 to 28 square feet, with improved evaporation and considerable saving in fuel. The grate area for megass furnaces was generally too large, and he believed

(Mr. Robert Graham.)

that at Puunene they would save a much larger quantity of megass if the grate area was further reduced.

Referring to Mr. Martineau's remarks (page 962), the writer had already indicated (page 968) that charcoal filters would never do for sugar estates, unless it suited to make refined white sugars. In regard to the burning of the molasses instead of making rum, he expected the reason was that the United States internal revenue laws caused so much trouble and expense that it did not pay to make rum, considering the market there was for it.

In regard to Mr. Berthon's remarks (page 965) on electric driving for centrifugals, he thought there was little doubt that, seeing the late improvements in electric motors for such purposes, the electric motor would be the future drive for centrifugals and other machines in sugar factories. In regard to getting out of the cane the greatest quantity of sugar, Hawaii was well ahead of other sugar countries. This result had been obtained largely by their having adopted the nine-roll and crusher system driven by one engine, which with many other advantages gave a regular and steady feed to all the crushing plant. In the new factories in Porto Rico, they had just as good nine-roll mills as in Hawaii, but had driven each mill by a separate engine, and, although they had quite as good canes as in Hawaii, the best extraction they had obtained was 80 lbs. of juice to the 100 of cane against the average in similar factories in Hawaii of 84 lbs.

Mr. DRUITT HALPIN wrote that one speaker, in referring to the amount of sugar actually existing in the cane, remarked that twenty years ago analysis showed the total amount contained in the cane did not exceed 9 per cent., but the author of the present Paper stated that they were obtaining as much as 13 per cent. It was not quite clear from the Paper whether the present mill was dealing with cane specially planted for its use, or, whether this mill was supplementing older mills having cane previously in cultivation, and it would be well if the author would say whether the cane used was first year's cane or had been ratooned. From time immemorial cane had been propagated from cuttings, and this has taken place to such an

extent that it was impossible to grow it from seed, as the seed from long disuse had ceased to be fertile. A few years ago the authorities at the Royal Botanical Gardens, Kew, turned their attention to this matter, and, after very prolonged experiments, eventually succeeded in restoring to the cane seed the power of germinating; the higher yields now obtained might possibly be owing to the mills dealing with cane produced from seed, or from cane which it had been impossible previously to hybridize, and thus improving its qualities. The yields of cane in weight did not seem to be larger per acre than the writer had to deal with forty years ago, where sixty tons per acre was not unusual, although, of course, this cane did not contain anything like the percentage of sugar now referred to in the Paper.

With respect to the system of using a preliminary macerator and then three very powerful mills in series, it was obvious that the megass must be ground into something like the consistency of fibrous snuff, which necessarily must produce difficulty in burning. Taking the power of the engines as 320 H.P., this would give 1·5 H.P. per square foot of roller, and if 600 H.P. were used, as was stated to take place occasionally, this would bring the H.P. up to 2·81 H.P. per square foot of roll, an old and satisfactory rule for ordinary single mills being 1 H.P. per square foot of roll. In addition to the enormous quantity of power taken by this unusual heavy crushing, there was the disadvantage, when it was resorted to, that certain residual gums and other undesirable matter were crushed out of the bark of the cane, which were known to be inimical to the production of the maximum quantity of sugar.

It would be of interest if the author would state how often they were obliged to sweep out the tubes of their boilers, as it appeared this would require to be done with unusual frequency, owing to the condition of the fuel as well as to the very good draught used, and it would also be well to know how often clinkering the furnaces was done, and how it was carried out in the construction shown, this question being of importance owing to the large amount of silica contained in the skin of the cane. It was stated that a certain amount of megass was stored as reserve fuel in front of the boilers.

(Mr. Druitt Halpin.)

Could the boilers be fired by hand with this fuel in the event of the automatic feed arrangements breaking down?

With regard to the system of treating the juice after it had left the mill, the writer was of opinion that the whole of the process of using sand filters resulted entirely from the way the juice was treated; certain parts of the fine fibre of the megass were removed by the simple mechanical filtration produced by running the juice over perforated gauze, but this did not at all provide for dealing with the scum existing in the juice, which could only be dealt with by heat and time. As the juice was stated to be raised to the temperature of 280° F. with a corresponding pressure, this scum was boiled into the juice in such a way as to make its subsequent removal most difficult, if not impossible. With the old clarifiers the juice was warmed up, exhaust steam passing under the bottom of the pan, and by the time the pan was full the scum had risen up to the top, and the juice at the bottom of the pan could be drawn off in a clear state, but if by any inadvertence the pan was allowed to boil, thus breaking the layer of scum, it was practically impossible to get the dirt out of the sugar and to make either good grain or good colour. It was stated that, when the sugar was let down out of the vacuum pans, it was sent direct into the centrifugals; this the writer considered was certainly not conducive toward producing large grain, which was one of the most important desiderata in sugar making. A better plan was to let the sugar down into coolers, as it was known that the more slowly the crystallization took place the larger the crystals became, and that the sugar had no chance of this beneficial arrangement was shown by the statement that, even when it came out of the centrifugals, it had to be thrown through the air in order to cool it.

One or two speakers expressed their great surprise at the fact that no rum was made at this factory, which certainly seemed to be a waste of a very valuable by-product. With reference to the amount of crystallization, it appeared that the process was used for the thirds, where it could be of less benefit than if used for firsts. One speaker referred to the proportions adopted in the vacuum pans, but he did not draw attention to the fact that the English practice of having a

much shallower pan was preferable, as amongst other advantages it presented a larger area of surface for the withdrawal of the vapour in proportion to the contents of the pan than existed in the American pans.

It was stated (page 937) that 40,000,000 gallons of water were pumped per day to an average height of 235 feet. If the gallon was taken at the English rating this would amount to 1,978 W.H.P., or if at the American rating to 1,645 W.H.P., and if an efficiency of 75 per cent. was assumed, this would amount respectively to 2,600 I.H.P., and 2,200 I.H.P., which appeared to be kept going day and night during the dry season. It would be well to know whether this was actually a fact, or whether some clerical error had crept into the figures.

Mr. John Laidlaw, of Glasgow, wrote that the illustrations, which appeared at the end of Mr. Williams' most instructive Paper, showed that the mill-engine was worked expansively. Since all the exhaust steam was used for evaporating purposes, it might be pointed out that a high degree of expansion did not effect any economy in heat. The work which a steam-engine was called upon to perform, being definite in quantity, was measured by the thermal units lost by the steam in passing through it; and as a smaller engine would always absorb less power to overcome its internal friction, it followed that the conversion of a definite amount of heat into its corresponding equivalent of work was best effected in the smallest engine which could be employed. By using steam at boiler pressure for nearly the whole length of the stroke, the engine could be kept to its smallest dimensions, and there was obviously no advantage in saving steam by working expansively, so long as it was necessary to supplement the supply of steam in the low-pressure mains by direct steam from the boiler.

The inertia of the centrifugal basket, acting as a fly-wheel, was sufficient to compensate any slight fluctuations in the pump. Even with a single cylinder pump, the running of the centrifugal had been found to be uniform; the use of an air-vessel was therefore unnecessary. Where a number of centrifugals were driven by one prime mover, the water-driving was the only system in which the

(Mr. John Laidlaw.)

motive power was applied direct from the prime mover to the centrifugal spindle, and was the only system in which the absorption of power was regulated in a direct manner in accordance with the amount of work to be done, and at the time when such work was required to be done; that is to say, in the water-machine the prime mover moved faster or slower according to the number of machines which might be running together. Mr. Berthon's remarks (page 966) as to the steam consumption of a water-driven installation were not quite to the point, unless he at the same time specified the work which was done during a given time; for the amount of steam used would bear a definite ratio to that work, and, if no work at all was being done the steam consumption would be very small. On the other hand, a belt-driven or electrically-driven installation would use a large quantity of steam, even if the centrifugal machines were partly or wholly idle; and at all times there would be a constant waste of power in the repeated changes of form which the energy of the steam had to undergo in its transmission from the prime mover to the centrifugal.

Exhaustive tests, made in a large London refinery many years ago at an early stage in the history of the water-driven centrifugal, for a period of six months, had proved that the consumption of steam for a given amount of work done was substantially the same in a water-driven installation of centrifugals as in a belt-driven installation, and since that time important economical improvements had been effected in the water-driven system. The author gave the total average horse-power for the crushing plant of the factory as 450 H.P. (page 935), and a very liberal allowance would apportion 90 H.P. to the work of driving the centrifugals. Let it be supposed, for the sake of argument, that half the power necessary to drive the centrifugals could be saved, the economy would only represent about 8 per cent. of the power required to run the crushing and centrifugal plants; so that, if any substantial saving in steam was desired, there appeared to be greater opportunities elsewhere than in the steam-engine or pump used by the centrifugals.

With reference to Mr. Brown's remarks as to the speed of the "Weston" centrifugal (page 950), all 30-inch machines made in

this country from the time it was first introduced in 1869 until about 1881 were run at 1,440 revolutions per minute, giving a periphery speed of over 11,000 feet per minute. Larger machines were made to run at the same periphery speed, for although they thereby developed a lower centrifugal force, they were generally used for the finest sugars. About 1881, the 30-inch "Weston" was sent out by the makers to run at 1,200 revolutions, or a periphery speed of 9,400 feet per minute, and this practice had continued to be more or less general to the present time. As regards the amount of sugar cured per hour, there were 40-inch water-driven centrifugals made in this country and working on "Ysabel" estate, Cuba, and elsewhere, each machine regularly curing 3,000 lbs. per hour, which corroborated Mr. Williams' figures. In all these cases the machines were driven by an ordinary duplex pump without any air-vessel.

Mr. Berthon had referred (page 965) to the electrically-driven centrifugal as a novelty. This statement, however, was hardly accurate, inasmuch as the direct-electrically-driven centrifugal had been in extensive use on the Continent for over fifteen years, and, as long ago as 1884, a direct-electrically-driven "Weston" centrifugal machine had been made under the patents of Mr. Alexander Watt and regularly worked with entire success in Messrs. Macfie's refinery in Liverpool. A more recent three-phase plant was described in the "Electrical Review" of 9th January 1902. Mr. Berthon was surprised that the amount of power absorbed in driving a centrifugal machine at full speed was the same whether the machine was loaded or unloaded; the cause, however, was quite simple. When the basket was empty, the windage through the open perforations was considerable, but at the same time the load on the footstep bearing was small. With the basket loaded, there was less windage because of the closing of the perforated surface by the sugar, but there was a greater load on the bearing. The friction appliance, described by Mr. Berthon as consisting of "plungers shod with leather" (page 965), was simply a modification or adaptation of the "Weston" friction-pulley known to all users of belt-driven "Weston" centrifugals, and had all the defects of that pulley. A somewhat similar application of the pulley to the electric-driving of centrifugals

(Mr. John Laidlaw.)

appeared in "Engineering" of 20th June 1902. An outstanding defect of the system consisted in the fact that 50 per cent. of the power under transmission was wasted in friction during the period of acceleration.

Mr. Berthon drew attention to the circumstance that when all the molasses had left the basket of a centrifugal, and there was a consequent fall in the demand for power to drive it, the maintaining jet of the water-driven centrifugal continued to do some needless work on the wheel. It was usual to stop the centrifugal at this stage, so that no useful purpose was served by continuing to run the machine after all liquid had been expelled. In point of fact, the electro-motor only approximated the water-drive in efficiency as the end of the run was reached. From actual tests, under average working conditions in Colonial sugar factories, it was found that, for a given amount of work done, over 60 per cent. greater power was indicated in the steam-cylinder of an engine driving electrical centrifugals than was indicated in the steam-cylinder of a pump driving water-driven machines. This economy was due to the smaller number of transformations of energy, as had already been mentioned, which the water-drive necessitated in comparison with the electric drive.

The following Table 1 showed this point clearly :—

TABLE 1.

	Kind of Drive.		
	Water.	Belt.	Electric.
Prime Mover . .	Steam-Pump.	Steam-Engine.	Steam-Engine.
Transformer. . .	—	—	Dynamo.
Driver	—	Countershaft and friction pulley.	Motor.
Centrifugal driven by	Pelton wheel on centrifugal spindle.	Belt pulley on centrifugal spindle.	Friction pulley on centrifugal spindle.

A London firm of refiners, who, after a few months' trial of a single electrically-driven centrifugal, had ordered six of the same machines, was instanced as evidence of the superiority of the electrical system of driving. It should likewise have been made known that the same firm simultaneously ordered additional water-driven machines on the strength of an eighteen months' trial of four such machines, and also a number of electrically-driven machines of a different type to those referred to, from the firm supplying the water-driven machines; so that the condition of their reference would appear to be wholly experimental. In neither case was it a safe deduction, that such orders decided the merits of a particular machine, for the opposite case could be equally proved by stating that a leading firm of German engineers, after a year's trial of eight water-driven machines, were now placing orders for more; or that another eminent German engineering firm ordered large numbers of water-driven motors for their centrifugals, although they were makers of electrically-driven centrifugals of many years' standing. At the present moment the makers of the water-driven centrifugals were making three-phase electrically-driven "Weston" centrifugals with baskets 6 feet diameter and floating spindles, for a refinery where there was a three-phase electrical system already established.

Since Mr. Berthon pointed out that he acted as engineer for the owners of the estate in Trinidad to which electrically-driven machines had been sent, the fact did not prove any superiority of such machines over the water-driven, but could only be taken as indicating Mr. Berthon's preference, and that he did not see any advantage in having machinery of simple construction on a sugar estate in preference to that which had considerable complications. Careful experiments and observations had been made of the power required to drive a standard 30-inch centrifugal (by the different methods of applying that power) under the average conditions that obtained on a sugar estate, namely, the output of the centrifugal being reckoned at one ton per hour of first sugars in ten charges of six minutes each, and with an average boiler pressure of 60 lbs. per square inch, and an average back pressure of 10 lbs. per square inch above the atmosphere in the low pressure mains, with an ordinary

(Mr. John Laidlaw.)

Power required to Drive a Standard 30-inch Centrifugal.

Fig. 15.

Water Drive Diagram.
Average I.H.P. 3·58.
Efficiency 40·6 per cent.

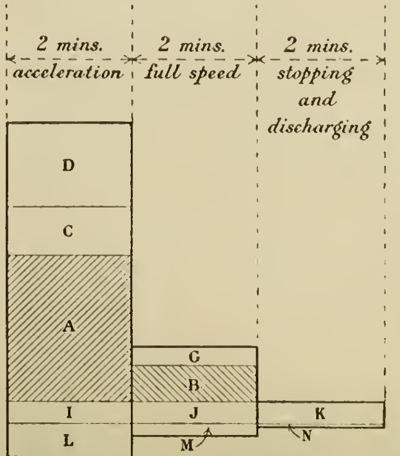


Fig. 16.

Belt Drive Diagram.
Average I.H.P. 4·85.
Efficiency 30·0 per cent.

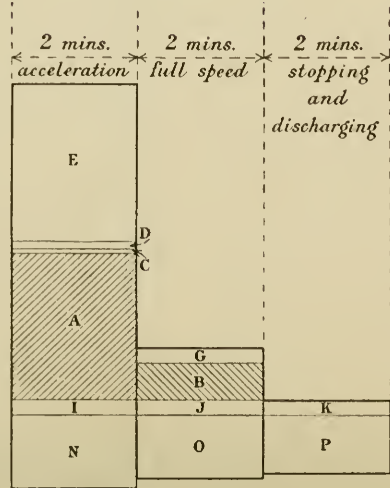
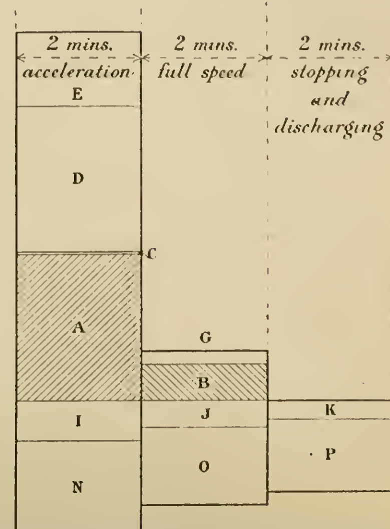


Fig. 17.

Electric Drive Diagram.
Average I.H.P. 5·91.
Efficiency 24·6 per cent.



The total area of each diagram represents the whole work done by the steam for each method of driving. The shaded part A represents the useful work during acceleration, and the shaded part B the useful work at full speed. The efficiency is therefore in the ratio of the area of the shaded parts to the whole area of each diagram. The shaded areas A and B are respectively equal in each diagram.

PARTICULARS OF ABOVE DIAGRAMS.

	Foot Pounds.		Foot Pounds.		Foot Pounds.
Acceleration Period.					
A. Inertia, friction and windage	= 230,315	A. Inertia, friction and windage	= 230,315	A. Inertia, friction and windage	= 230,315
C. Loss of wheel due to splash, etc.	= 76,772	C. Inertia of pulleys and belt	= 6,000	C. ,, of motor armature	= 2,000
D. ,, ,, ,, variable speed	= 131,609	D. Friction and windage of ditto.	= 12,375	D. Loss in friction pulley	= 230,315
I. ,, due to leakage of pump	= 35,570	E. Loss in friction pulley	= 248,690	E. Motor loss	= 115,657
L. ,, ,, friction	= 52,696	I. ,, countershaft and arms	= 24,750	I. Loss in dynamo	= 64,254
		N. Loss due to engine	= 114,614	N. ,, engine	= 141,045
Full Speed Period.					
B. Friction and windage	= 57,750	B. Friction and windage	= 57,750	B. Friction and windage	= 57,750
G. Loss of wheel due to splash, etc.	= 28,875	G. ,, ,, ,, of belts and idlers	= 24,750	G. Motor loss	= 19,250
J. ,, due to leakage of pump	= 35,570	J. Loss in countershaft and arms	= 24,750	J. Loss in dynamo	= 43,527
M. ,, ,, friction ,,	= 19,761	O. ,, due to engine	= 99,453	O. ,, engine	= 122,388
Stop Period.					
K. Loss due to leakage of pump	= 35,570	K. Loss in countershaft and arms	= 24,750	K. Loss in dynamo	= 30,436
N. ,, ,, friction ,,	= 4,790	P. ,, due to engine	= 92,141	P. ,, engine	= 113,389

(Mr. John Laidlaw.)

slide-valve engine for the belt and electric drives, and a common direct-driven steam-pump.

Figs. 15, 16, and 17 (pages 978 and 979) showed the useful work done and the waste which took place in each cycle of the operations, and it would be seen that the water-driven system took the least power and that the electric-drive took most. Whatever modifications of the conditions of working were considered to suit different grades of sugar, or whether the exhaust was usefully employed or discharged to the atmosphere, it would be found that the water-driving system came out ahead in point of economy of either belt or electric driving.

Mr. Howard Marsh, of Derby, wrote that, having been connected with the manufacture of cane sugar-producing plant for upwards of twenty-two years, the subject was a most interesting one to him. The first point referred to in the discussion was the acreage necessary to produce the quantity of cane dealt with at the factory described by the author, and the difficulty likely to be experienced in getting the cut canes delivered alongside the milling-plant expeditiously. He himself did not see that there was necessarily any great difficulty in this direction. It was pointed out by the author that the factory was situated in the centre of the cane-fields, so that given sufficient and efficient rolling stock and a sufficiency of hands in the cane-cutting and carrying gangs, capable management would accomplish the task. Of course, if the factory were placed in a locality where the canes had to be conveyed to the mills by punts, or where the land was otherwise than level, the case would be different; but even in places where the ground was too uneven to admit of easy transport by means of rails, a good deal could still be accomplished by means of aerial railways, etc. He would very much have liked to hear Mr. Berthon express his views on this subject; his connection with a firm owning plantations covering large tracts of cane-growing lands in Trinidad would have enabled him to speak with authority on this point. About a dozen years ago he himself paid a flying visit to a factory in Guadeloupe which, to the best of his recollection, dealt with about half the quantity of cane worked up at the Kahalui-Maui

factory. In the case of the Guadeloupe plantation the factory was situated close to the shore of a bay, and part of the canes were brought across the same in punts by tugs, and it was clear that the factory could not be so conveniently situated for the supply of canes as it might be; however, he did not think that any inconvenience was caused through canes becoming acid on account of delays in transit.

With regard to the milling-plant, no objection could be taken to the driving of the nine rollers and crusher in each set by one engine; as there were three sets of mills, an accident to one would still leave two sets available for carrying on the work. Where, however, a factory was equipped with one set of mills only, the question was whether independent engines were not preferable, as breakdowns could not always be avoided, and it was a most serious matter when grinding had to be discontinued, even for a comparatively short time, while the crop was being reaped.

Some comment was made during the discussion upon the use of sand filters. He did not quite gather whether it was the use of sand instead of charcoal which was adversely criticised, or whether it was the form of the filter which was referred to, but he rather thought that the speaker intended to convey that he would have preferred the use of charcoal filters. In connection with this he would point out that sand was a purely mechanical filtering agent, that is, it merely retained flocculent matters which had been precipitated by the treatment of the mill liquor (juice) in the liming tanks and heaters, and which had escaped removal by the decanting process in the settling tanks. Charcoal, on the other hand, might be considered to be a chemical as well as a mechanical filtering agent, inasmuch as it not only removed the solids, but it also had a decolorizing effect upon the liquor. As they only manufactured raw sugar at Kahului-Maui, it was not necessary to decolorise the liquor; it need scarcely be pointed out that charcoal filtration was very expensive in first cost and upkeep, whereas sand or other similar mechanical agents were very much cheaper in every way, and, in the case of raw sugar manufacture, were quite satisfactory.

(Mr. Howard Marsh.)

In connection with the boilers, it would be interesting if the author would furnish some further particulars of the setting of these, showing the course taken by the flames and heated gases on their way from the furnace through the boilers to the chimney. The length of the boilers was referred to in the discussion as being unusually great in comparison with the diameter of the tubes; he would, however, be loth to criticise the design of the boilers without having further information concerning their setting and, if possible, the intensity of the chimney draught.

With regard to the vacuum pans, it was remarked by Mr. Brown (page 949), that the amount of the heating surface and the number of the coils mentioned by the author indicated that these coils were unusually long for their bore; he gathered, however, from Plate 85, that the coils were not single coils, but were at least double and possibly triple in form, which of course materially lessened the length of the passage of steam from valve to tail pipe; further, he was inclined to think that, although the author mentioned that the pans were designed for working with either direct or exhaust steam—whichever might be required—they would be more particularly adapted for the use of direct steam, as he thought it probable that there would not be a sufficient supply of exhaust steam to serve the pans. The mill-engine diagrams, Plate 89, indicated that the engines had been designed with a view of economy in the use of steam, and as the bagasse from the first and second grindings was in each case macerated, it was likely that practically the whole of the exhaust steam was utilized in the evaporators and heaters, and consequently the bulk of the work was done in the pans by means of direct steam from the boilers.

Mr. Williams, in replying to the discussion, wrote that to keep this factory going at the rate of 3,600 tons of cane ground per twenty-four hours would require the harvesting of 60 to 70 acres per day during daylight, since field work at night was not practicable. This meant a field yield of 50 to 60 tons of cane per acre (a fair yield for this plantation); there was a crop acreage of 9,000 to 12,000 acres, and a total acreage under cultivation of from 30,000 to 35,000

acres, since three crops were in hand at once. One of the points aimed at in the construction of so large a sugar works was the ability to reap an immense crop during the months the cane was at its best; experience had conclusively shown that the increase in the sugar yield from the cane due to reaping at the right time, and the reduction in the manufacturing cost of the sugar bagged due to a highly organised plant of great capacity, far outweighed the loss of interest on the heavy investment of capital represented in buildings and machinery idle during the remainder of the year.

The class of sugar turned out was for sale to the refineries in the United States; no special effort was made to produce a handsome well-coloured crystal, but the object kept constantly in view was to produce that grade of sugar which kept best on the voyage to San Francisco or New York, and at the same time gave a high yield on the available sugar in the syrup, and which produced the most money per ton of cane ground. A sample * marked # 2 would give a fair idea of grade A sugar shipped from the Hawaiian Islands to the American refineries. It might be stated that this sample of sugar contained on the day of manufacture 96·1 per cent. in pure sugar, and cargoes of similar sugars of the same or nearly the same test had turned out on arrival at New York from 96·5 per cent. to 96·8 per cent. pure sugar, with of course a reduction in weight to correspond to the increase in purity. The sand filters mentioned (page 920) were installed for the purpose of removing a fine impurity held in suspension in the clarified juices, and not for the purpose of decolorising or purifying in any way the sugar solutions.

Referring to Mr. Brown's query (page 948) regarding water delivered by evaporators and used for feed make-up for boilers, etc., the statement in the Paper (page 920) was strictly correct. The condensation inside the heating tubes of the first body of the evaporator resulted from exhaust steam, and was pumped back directly into the feed pipe to the boilers without passing through the hot-well, by special pressure pumps under the control of a float

---

* The author forwarded to the Institution four samples of sugar and some surplus bagasse, which he thought would be of interest to the Members.

(Mr. Williams.)

governor, and connected to the first bodies of each evaporator. The condensation in the heating tubes of the second, third, and fourth bodies of the apparatus resulted from the vapours given off by the juice and syrup under operation in the first, second, and third bodies, and this water, being delivered in a state almost chemically pure, was used for various purposes, such as feed make-up for the boilers, maceration water for the crushing plant, etc., etc. This water travelled from body to body, drawn over by the difference in pressure, and was withdrawn from the heating side of the 4-inch body against the vacuum existing therein, by a special pump and was delivered into a tank whence it was distributed over the building. The vapours rising off the syrup, during the final thickening or stage of concentration in the 4-inch body, were condensed in an ordinary jet-condenser, to which was attached a powerful vacuum pump as described. Entrainment, or the carrying over of minute globules of syrup with the vapours, did not occur in this apparatus, provided that the heating surface was not forced to evaporate more than from 4 to 5 lbs. of water per square foot of heating surface per hour out of the juice or syrup under operation; careful and numerous tests had shown that the amount of sugar present in the water, resulting from the condensation of the juice vapours, did not exceed 0·004 per cent. (four thousandths of one per cent.), an amount so small as to be perceptible only to the most delicate tests, and which meant simply nothing at all to the practical man.

Regarding Mr. Brown's criticism of the vacuum pans (page 949), and arrangement of coils, it might be said in reply that the pans in question had never given any trouble, that no difficulty was experienced in taking off from thirty-three to thirty-seven tons of dried sugar per strike. The time of boiling averaged about seven hours. It was considered that seven hours was not too much time to allow in boiling large strikes or cookings of sugar, if a good hard sharp commercial grain was to result. Opinions might differ on this point, but the fact remained that these pans were in successful use, and no reason existed why any change should be made. The heating surface in each of these pans was one thousand square feet in two thousand running feet of coils, the capacity of each pan to

strike line was twelve hundred cubic feet, consequently one square foot of coil surface served 1·2 cubic foot of pan capacity, which compared not unfavourably with English and German practice. The multiple inlet coil illustrated by Mr. Brown, Fig. 13 (page 949), was thoroughly tested in the Hawaiian Islands some years ago, and was not considered a success for the work there.

In reply to the question as to the construction of the 40-inch centrifugal baskets for a speed of 1,000 revolutions per minute (page 950), the baskets were made of sheet brass about $\frac{1}{4}$ inch thick, pierced with $\frac{3}{16}$-inch holes, about 1 inch centres. The basket was riveted up, having external butt straps on opposite sides so as to balance, and it was strengthened by weldless steel rings shrunk on the outside of the basket; these rings had a cross section of $\frac{5}{8}$ inch by $1\frac{1}{4}$ inch and were set about 4 inches apart, Fig. 18, Plate 91. To his knowledge no accidents had ever occurred with these machines, and hundreds were in use.

Regarding the extremely high air-chamber (page 950), which was 24 inches internal diameter, and which was charged with air at 60 lbs. pressure on commencing operations, the length of air cushion (under 180 lbs., per square inch water pressure) was about 20 feet; the pump cylinders were 12 inches diameter and 24 inches stroke, duplex direct acting, having 22-inch steam cylinders. Supposing that all the machines were suddenly stopped, then because of the long and capacious air-cushion in the head of the chamber, the pump would make a few strokes before the pressure could rise very much, and this gave time to the pump regulator to act on the steam-valve to cut off the steam; similarly, if all the machines were thrown on at once, the long air-cushion was a reservoir of power which immediately assisted the pump in keeping up the pressure for a few seconds, until the steam valve could be acted upon to admit more steam and speed the pump up to requirements, and so on between these extremes. The high air-chamber, then, when used in connection with a duplex direct-acting water-pump, acted as a fly-wheel; and the results were such, that whereas where the direct-acting pump was used without the long air-chamber, one pump of the size given would operate eight 40-inch machines only, but with the long

(Mr. Williams.)

air-chamber the same pump served sixteen 40-inch machines and apparently worked much easier.

With regard to the statement made in the Paper respecting the loss of moisture by the bagasse on its way from the last mills to the furnaces, the statement as made was fairly accurate, as might be seen from the following:—One pound of bagasse, as it naturally fell, occupied a space of some 200 cubic inches and exposed a surface of about $2\frac{1}{2}$ square feet to the action of the atmosphere. The average humidity of the atmosphere, as shown by a wet and dry bulb thermometer, was 57 per cent. at 75° F. The mean temperature of the bagasse between mills and furnaces was 125° F., and the average time required to travel the distance from mills to furnaces was seven minutes, as the conveyors ran very slowly. Further, the bagasse was dropped from the head of the inclined elevator about 7 feet to the conveyor running across the building; it was again dropped from that conveyor another 4 feet into the longitudinal conveyor, running over the furnaces, and then fell about 10 feet down a chute into the fire, so that the bagasse was turned over and over in its travels, thus exposing every particle to a drying action of a very dry atmosphere. By the formula of Mr. Thomas Box, "Practical Treatise on Heat" (page 152)—

$E = \{243 + (3\cdot7 \times t)\} \times (V - v)$; wherein E = evaporation in grains per square foot per hour;

t = temperature of water (in bagasse) = 125° F.,

V = elastic force of vapour at temp. $t = 3\cdot93$,

v = elastic force of vapour present in air = $\cdot868 \times 0\cdot57 = 0\cdot49476$;

then $E = \{243 + (3\cdot7 \times 125)\} \times (3\cdot93 - 0\cdot49476) = 705\cdot5 \times 3\cdot43{,}524$.

$E = 2{,}423\cdot6$ grains per square foot per hour, and since $2\frac{1}{2}$ square feet were exposed during seven minutes of time, the evaporation = $\frac{2423\cdot6 \times 2\cdot5 \times 7}{60}$ = 707 grains evaporated per pound of bagasse, which bagasse contained $\frac{7000 \times 45\%}{100}$ = 3,150 grains of water.

Percentage of moisture in bagasse evaporated = $\frac{707 \times 100}{3150} = 22\cdot4$

per cent., and this was confirmed by considering the case on a B.Th.U. basis.

In replying to Mr. Brown's last question (page 952) as to relative cost of cane and sugar in 1882 and 1902, the author wished to say that in arranging the scope to be covered by the Paper under discussion, the commercial and agricultural sides of the Hawaiian sugar industry had been purposely left out, as tending to enlarge the subject, so that adequate treatment could not be given in the time available; and as the engineering side of the industry was the one that would be most interesting to engineers, that subject was chosen for the Paper written. The author would, however, endeavour to answer briefly the question put. In 1882 the average yield of sugar per 100 of cane was about 9 lbs. and the average yield of cane per acre was about 25 tons, the "net proceeds to the plantation" of commercial sugar after all marketing charges, freights and commissions had been paid, was about $75·00 say £15 10*s.* per ton of 2,000 lbs. In 1902 the average yield of sugar per 100 of cane had been about 12 lbs., and the average yield of cane per acre had been about 40 tons, the net proceeds of commercial sugar after all marketing charges, etc., were paid did not exceed $50·00, say £10 10*s.* per ton of 2,000 lbs.

The cost of cane per ton of 2,000 lbs., delivered on the cane carrier in 1882, was not less than $3·00, say 12*s.* 6*d.*, and the cane last year did not cost less on an average than $4·50 per ton, say 18*s.* 9*d.* The above were average figures, and were not far from the truth, for the whole group comprised in the Hawaiian Islands. It would be at once seen that, in 1882, 11 tons of cane were required to make one ton of sugar; cane per ton of sugar cost then $33·00. In 1902, 8½ tons of cane sufficed to make 1 ton of sugar; cane per ton of sugar cost $38·25. The cost of manufacturing sugar in 1882 was not less than from $10 to $12 per ton, while in 1902 it averaged about $5·00. In explanation it might be said that the term "net proceeds to the plantation" meant that sum of money received per ton of sugar after marketing, out of which all management expenses and agricultural, manufacturing and financing expenses must be paid before any division of profits (if any) could be declared. It would

3 x 2

(Mr. Williams.)
therefore be evident that while cane cost less in 1882, sugar cost more to make; and in 1902 the increased expense of producing cane was just about balanced by the reduced cost of manufacture, due to improved machinery and methods. It would also be clear that the Hawaiian planters and sugar producers had had to face no small drop in prices. The well-appointed plantations, powerful and efficient machinery, and very complete system of accounts in every branch of the industry were the results of a reduction in net profits, very great in itself, but spread over a considerable period of time, so that opportunity was afforded to those who had courage and energy to devise new methods to meet changed and changing conditions.

Replying to the surmise of Mr. Abell (page 955) respecting the progress made during twenty years in manufacture of sugar and cultivation of cane in the Hawaiian Islands, it could be stated that the improvement in yield of sugar per 100 of cane was almost entirely, if not fully, due to improved machinery and methods of manufacture, while the increase in tonnage of cane per acre was entirely due to a scientific application of high-class fertilizers. Cane could not be grown upon four-fifths of the sugar lands of the Hawaiian Islands without irrigation, which had been practised much the same from the earliest days of the industry as at the present time. Intensive cultivation of cane had only reached its present stage in that country within the last few years, and the results on certain lands had been almost beyond belief, as much as 110 tons of cleaned cane ready for milling having been produced per acre from large sections of land, the cane yielding 12½ per cent. of commercial sugar on its weight. Such favoured spots, however, were scarce, and the yields from them in no way affected the statements as to general averages.

Taking up Mr. Abell's criticism (page 953) of the boiler design, and the results obtained by the bagasse as fuel together, it could be said that the boiler described in the Paper was in very general use in that country, and had given all-round better results than any other type of either water-tube or fire-tube boilers, and almost every conceivable combination of boilers had been tried at one time or another. Economy in the construction and setting of a large boiler

plant, such as described, required to be studied, as well as economy in operation; it required no argument to prove that a boiler of small diameter and long tubes was cheaper to make, and to set, per square foot of heating surface, than a boiler of large diameter and short tubes. Given two boilers of equal heating surface, equal grate surface, equal draught, the amount of fuel consumed per unit of heating surface, and per unit of time about the same, and the temperature of the waste gases at exit from boilers alike, the efficiencies of the two boilers must be practically the same, since the heat developed by the combustion of the fuel either went into the water in the boiler or up the chimney (leaving radiation out of the question). The factory mentioned by Mr. Abell must have been rather a small one and was probably worked up to its full capacity. During the last crop, the Hawaiian Commercial Sugar Co.'s factory only worked up to one-third of its full capacity, while the heat radiating surfaces of the great range of steam pipes installed for the full capacity of the factory, even thoroughly clothed as they were, dissipated a large amount of heat, which had to be supplied by the bagasse from one-third of the ultimate quantity of cane to be ground. Again, little or no maceration water was used in the Demerara factory, while in the Hawaiian factory, maceration to the extent of eighteen gallons of water per 100 gallons of original juice was applied, and this represented a considerable amount of extra evaporation to reduce the thin juice to the consistency necessary for the vacuum pans. Further, it was well known that to manufacture sugar required more steam than it did to make rum, and the Hawaiian factory produced 30 per cent. more sugar per ton of cane than was obtained at the Demerara factory.

Still another fact, which must not be lost sight of, was the difference in the weight of bagasse per 100 of cane. Assuming that the sugar produced in Mr. Abell's factory was 10 per cent. on weight of cane—and this must be very near the correct figure—100 lbs. of Demerara cane produced 30 lbs. of bagasse and 70 lbs. of juice; while in the Hawaiian factory 100 lbs. of cane produced 24 lbs. of bagasse and 92 lbs. of juice (including maceration water). With 20 per cent. less bagasse, the Hawaiian factory had to make 30 per

(Mr. Williams.)

cent. more sugar, and evaporate 32 per cent. more water out of the juice than the Demerara factory. The addition of molasses aided the fuel qualities of the bagasse very materially. The total waste molasses for last crop amounted to $4\frac{1}{2}$ gallons per ton of cane ground; this amounted to 2·8 lbs. per 100 lbs. of cane, which added to the 24 lbs. resulting from the grinding of the cane gave available fuel per 100 lbs. of cane of 26·8 lbs., which was still considerably less than the amount available in the Demerara factory. The following comparative Table supplemented the foregoing:—

TABLE 2.

	Hawaiian Factory.	Demerara Factory.
Cane ground per hour . . . . . . lbs.	85,400	28,000
Sugar made per hour . . . . . . lbs.	11,200	2,800
Bagasse, including molasses, per hour . . lbs.	22,887	8,400
Bagasse per 100 lbs. sugar made . . . lbs.	204	300
Water to be evaporated out of juice per 100 of cane lbs.	69	52·5
Number of boilers in use	6	5
Total heating surface in boilers . . . sq. ft.	15,600	6,500
Total grate surface. . . . . . . sq ft.	216	100
Ratio of grate surface to heating surface . . .	1 to 70	1 to 65
Temperature waste gases . . . . . F.	540°	500°
Heating surface in boilers per 100 lbs. sugar made per hour . . . . . sq. ft.	140	232

It would therefore be seen that the efficiency of the boiler plants, when stated in terms of heating surface in boilers per 100 lbs. of sugar per hour, was as 1·66 is to 1 in favour of the Hawaiian factory, which would of course be reduced if it were known exactly how much steam was required to distil proof spirit, as compared with the steam required to manufacture an equivalent amount of sugar. But sufficient had been stated to show clearly that the Hawaiian factory,

working at one-third of its ultimate capacity, and therefore not at its best as regards economy of fuel, did not suffer by comparison.

Regarding the question of commercial efficiency brought up by Mr. Abell (page 956), it seemed strange that at this day of gigantic industrial enterprise, any question should arise concerning the advantages to be derived from the operating of great and highly organized manufacturing establishments. The cost of producing sugar in this factory when working 1 unit only, or one-third of its ultimate capacity, was 14 cents., say 7*d.* per 100 lbs. The cost so far during this crop now in course of reaping and working two units, or two-thirds of full capacity, was 10 cents., say 5*d.* per 100 lbs. of sugar. When the factory was working at its full capacity the cost would be proportionately lower, showing an increasing commercial efficiency as the out-put was increased. The above cost included all expenses from cane in cars to sugar in sacks, excluding cost of bags or depreciation charges on machinery, but inclusive of every other expenditure connected directly with manufacturing, such as labour, skilled and unskilled, materials and repairs, etc.

Turning to the remarks of Mr. Llewellyn Jones (page 958) respecting the methods of applying maceration water on the crushed cane between the different mills, the author would say that water pipes $1\frac{1}{4}$ inch diameter pierced with very small holes about $\frac{1}{32}$ inch diameter, spaced about 1 inch apart, were arranged one over the back roller of the first mill, one over the front roller of the second mill, one over the back roller of the second mill, and one over the front roller of the third mill.

The juice expressed by the action of the third mill was very low in density and was strained, and by the use of a small steam ejector was thrown on the bagasse as it left the first set of rollers, and acted as maceration water by diluting the residual juice in the crushed cane leaving the first rollers. Pure hot water delivered by the evaporating apparatus was used for maceration between the second and third sets of rollers; this water came to the mill room under about 40 feet ahead, and the velocity of the jets of water leaving the spray pipes was sufficient to drive into the fibre of the cane as it left the gap between top and back rollers

(Mr. Williams.)
of the mill; the amount of water was regulated by a valve having a graduated scale attached to the handle, so that, if it became necessary at any time to shut off the water, it could be turned on again exactly as before. The control of the maceration was kept as described in the Paper by the density of the juice expressed by the third set of rollers. It had been found that if sufficient water was applied between the mills to bring up the weight of the extracted juice to equal the weight of the cane ground, the maximum results were obtained in sugar extracted, and this proved a very convenient method of checking the mill work, of course presuming that the water had been properly applied.

Mr. Jones opened an old question in his criticism on the position of the hydraulic rams fitted to the rollers in the Hawaiian factory (page 959), and the question was the relative merit of rigid and flexible cane-crushing mills. It depended entirely on the method of working the mills whether the hydraulic rams should be applied to the top or to the side rollers. If the man in charge of the mills could not secure an even feed of cane on the cane carriers for any reason, and the difficulty could not be overcome in any other way, then to correct inequalities in feed of cane, hydraulic rams could be fitted to the back rollers with some advantage. But if a reasonably even feed cane could be secured, and this was the way in which the service was carried out in the Hawaiian establishment, then the hydraulic rams should be applied as they were, to the top rollers; in good and regular work with properly adjusted rollers the top roller should not move vertically more than $\frac{1}{16}$ inch unless some hard substance, such as a coupling-pin, bolt or other piece of iron should by accident go through the mills with the cane, and then the top roller should lift, let the intruder pass, and resume its place. If the bagasse packed so hard on the returner-bar as to raise the top roller, the setting of the bar was radically wrong and should be attended to at once; the top roller should be set so as to nip on the back bottom roller. The front bottom roller should be far enough away from the top roller so as to admit of the feed of crushed cane getting fairly into the jaws of the mill, otherwise in a bagasse mill, slipping would take place between the front and top rollers, and bad crushing, with slow work,

was the result. The hydraulic rams on the mills at the Hawaiian factory were there mainly as safety appliances, and good work in crushing was secured by means of an even steady feed on the cane carrier, supplemented by the delivery of a very even blanket of crushed cane from the crusher to the first mill. In all the controversy regarding "rigid" versus "flexible" mills, as far as the author knew, the palm for good crushing had always been allowed to the rigid mill, provided that an even feed of cane could be supplied. There were between fifty and sixty mills in the Hawaiian Islands, and only one was fitted with hydraulic rams on the back rollers.

In reply to Mr. Martineau (page 961) respecting the time cane will last after having been cut before being ground, it was customary, and indeed necessary, where cane was transported by railroad, that the cutters should be from one to two days ahead of the loaders; and the loaders were usually from 18 to 24 hours ahead of the mill, so that the lapse of time between cutting and grinding of cane was from 60 to 72 hours in Hawaii, but the cane did not appear to suffer. As had been stated before, the atmosphere was very dry, and the heat was not excessive; it was not nearly so warm as in Cuba or Jamaica, although in about the same latitude, so that liberties could be taken with sugar-cane there that could not be taken with safety elsewhere. Still, from 36 to 48 hours between cutting and grinding was common in Cuba, and no harm resulted.

With respect to arrangements for heating the expressed juice (page 962) on leaving the mills, this was done in the factory as soon as possible, but the juice, in the methods in use there, had to be tempered with lime previous to heating; to accomplish this properly was the most important operation in the factory. The juice, on leaving the mills, was pumped up to the liming tanks each holding 5,000 gallons; in ordinary work each one of these would be filled in 15 minutes when two mills were in operation. The lime-water was charged into the 5,000 gallons of juice in quantities determined by the use of litmus, phenolphtalein, or, as the author found the best, by the precipitation in the cold solution. The juice was then pumped through a heater, raised to the temperature required, and delivered to settling tanks, where the solids in

(Mr. Williams.)
suspension subsided to the bottom, the clear juice being drawn off afterwards; if sufficiently clear, the juice was delivered directly to the supply-tank serving the evaporators. If the deposit of suspended matter had not been good, the juice was passed through the sand-filters, which were used solely for the purpose of removing flocculent matter, etc., and, as had been stated before (page 983), not for the purpose of purifying or decolorising the sugar solutions as animal or bone charcoal would. The sand in the filters required frequent washing, and as a certain amount of sugar was lost during every washing of the sand, the filters were not used any more than could be avoided, but they were always kept ready for any emergency. Referring to drawing back the low-grade sugars into the vacuum-pan when boiling # 1 sugars, this was a recent development, and was not in general use everywhere as yet. It had been found when remelting low-grade sugars in hot water or in clarified juice that a net loss of from $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent. of the pure sugar in the low-grade stuff ensued. This was due to a fact well known to refiners, that no matter how stiff a sugar solution might be boiled, there would always be some water in the massecuite which would hold a certain amount of sugar in solution and restrain it from crystallising. Now, by drawing the dry grain of the low goods into the pan at the time the syrup therein showed a grain as having started, the solution in the pan was saturated, and therefore could not dissolve the entering crystals, but it would, so to speak, cleanse the low-grade crystals from the adhering molasses, and would immediately commence to build on a new grain, just as it did on its own grain, and the finishing of the strike proceeded as usual.

Again, another method recently developed was to use the low-grade crystals as seed; the pan was filled with syrup and boiled down to the graining point, and a heavy charge of low-grade crystals was drawn in, which were built upon as usual; this resulted in a much larger crystal than was common, and was practised when a very high-grade washed sugar was being made for local use. In theory this method was correct, since low-grade sugars of 84 to 86 per cent. pure sugar were just as high in purity as the syrup due to cane, the principal portion of the impurity or foreign matter in a sample of

low goods being water, the ash and glucose being trifling in comparison to sugar and water content. The gain by this method of treating low goods was that the less ensuing upon remelting was avoided. He had reason to believe that for every pound of pure sugar taken into a vacuum-pan in this way a pound of pure sugar resulted. Very sticky low goods were remelted, as it was not practicable to draw them into the pans dry. To illustrate this, four samples of sugar had been sent to the Institution for inspection. Sample # 1 was low-grade sugar from crystallizers polarising 89·4 per cent., of this 10 tons were drawn into a strike of 32 tons of # 1 sugar shown in sample # 2, which polarised 96·1 per cent. A portion of this was washed to produce sample # 3, which after washing polarised 99·8 per cent. A still lower grade shown in sample # IV was made resulting from tank molasses, and marked # IV, but this was always remelted for the reasons given above.

Regarding the burning of molasses he recognised the fact that it was wasteful, but under the Hawaiian Monarchy, laws against the manufacture of alcohol had always been in force; these laws were retained under the Republic, and since annexation to the United States was of recent date, it was not surprising that distilleries had not yet been established there. It was probable that in the near future molasses, instead of being a nuisance as it was now, would become a source of income; meanwhile they fed the live stock—all that it was safe to give them—and burnt the rest.

With reference to the request of Mr. Berthon for data as to the form of the rubbing surface of the returner-bar (page 965), a diagram was appended, Fig. 19, Plate 92. The construction of the bar was entirely of cast-iron, the blade was made so as to be easily removed when worn out, and was made of cast-iron, so that the edge next the front roller would crumble off as it wore, rather than roll up as a steel or wrought-iron blade-edge did. Cast-iron also did not punish the roll-surface to such an extent as steel did, and lasted fairly well, a new wearing-blade being required once every crop. The only rule known to the author for setting returner-bars was the "rule of thumb," but the figures given on the diagrams were accurate, and the setting had produced excellent results.

(Mr. Williams.)

Electrical drive for centrifugal machines (page 965) received some attention when the factory was being designed, and at that time (some three years ago) experiments had been carried out in the United States, but the degree of success attained did not encourage investigation into the merits of the case. After a good deal of discussion, water-driven machines were adopted for the use of this factory, and there was every reason to be thoroughly satisfied with their performance and staying qualities. Plans had been made for an adjustable nozzle for use on these machines so as to economise pressure-water as much as possible, but the range of power required was so great that considerable difficulty would be experienced in bringing the improvement to a successful issue.

A 40-inch machine when used on # 1 sugars should be brought up to full speed in about 45 seconds, otherwise, in a free drying sugar, a great part of the molasses would be thrown off before the sugar had "walled up" properly in the basket; that is, the wall of sugar inside the basket would be thicker at the bottom than at the top, and the sugar would be unevenly dried, as after the molasses had departed, the sugar wall would not alter its shape under the influence of centrifugal force, and the stiffer and dryer the massecuite was, the quicker should the machine be brought to drying speed. The kinetic energy in the revolving parts of a 40-inch water-driven centrifugal machine, when loaded with 700 lbs. of massecuite and running at 1,000 revolutions per minute, was $\frac{Wv^2}{2g}$ = foot-lbs., wherein

W = weight of revolving parts and charge = 2,000 lbs.

assumed to be concentrated at the radius of gyration = 18 inches.

v = 157 feet per second.

Then $\frac{2000 \times 157^2}{2 \times 32{\cdot}16} = 766{,}449$ foot-lbs.

Speed attained in 45 seconds.

Foot-lbs. per second, 17,032.

Power per second $\frac{17032}{550}$ = 31 H.P. nearly.

This was the theoretical power required. To obtain actual power required, the air resistance and friction must be added. To determine the air resistance and friction, a machine in ordinary work was

loaded, the charge dried, and then the water shut off and the machine allowed to stop of itself; the time required was 23 minutes and 43 seconds: in all, 1,423 seconds from the moment the water was shut off until the machine came to a standstill. Now since it required 766,449 foot-lbs. of energy to bring the machine up to speed, calculated on the load, this same amount of energy must have been given out in overcoming friction and air resistance, consequently $\frac{766449}{1423} = 538$ foot-lbs. per second, and this added to the theoretical energy would give a very close approximation to the actual, which was then $\frac{17032 + 538}{550} = 32$ H.P. nearly. And the air resistance and friction amount to a little over 3 per cent. of the total power expended. But to keep the machine running, after the bulk of the molasses had been given off, only required about 4 H.P., so it was clearly to be seen that an adjustable water-nozzle under automatic control would be a valuable improvement, and would tend to economy in the use of water-driven machines of this class. This was a rough calculation, as no notice was taken of the weight of the molasses driven off the massecuite, amounting to about 300 lbs. per charge. But the neglect of this factor did not materially alter the result, which showed the approximate range of power required in this size of centrifugal. The simplicity and ease of upkeep of the water-driven centrifugal was greatly in its favour, especially for use in out-of-the-way parts of the world. There was no doubt about the advantages attending the use of the electrical drive for centrifugal machines, but where fuel was no object, or in those sugar factories which had bagasse in excess, great refinement in steam economy, unless attained in simple machines, was usually attended by extra expense in other directions, which more than off-set the saving of steam. This would answer Mr. Berthon's criticism (page 966) on the use of direct-acting duplex steam-pumps for furnishing pressure-water for these centrifugals in the Hawaiian Co.'s factory.

In answer to the queries of Mr. Druitt Halpin (page 970), the author would say that the plantation had been established about twenty-five years; the factory was built to replace an old and worn-

(Mr. Williams.)
out establishment, which had become too small for the increased output. The cane was the ordinary cane of the country, part plant, and part ratoons, in proportion about five-eights plant and three-eights ratoons by weight.

Replying to the question regarding the cleaning of the boilers (page 971), this was done once a week, excepting when molasses was burnt, then two boilers had the tubes cleaned every day, the whole boiler battery being gone over in rotation. This was for the purpose of removing deposits of potash resulting from the molasses which, being sublimed in the furnaces, condensed on the tube surfaces and affected the draught. The furnaces were scaled and clinkered twice a day, and the ash-pit men kept going over the furnaces regularly. When the mills were stopped, the furnaces were fed by hand from the surplus bagasse, which was stored for the purpose on the bagasse floor. It would be a most unlikely thing for the bagasse-distributing arrangements to break down, but if they should for any reason become damaged, the mills would have to stop until the gear was repaired, as although it was possible to fire by hand for boiling off the house after the mills stopped grinding for the week, it would not be possible to fire by hand and keep the mills and boiling-house properly supplied with steam.

In reply to the criticism on methods of clarification (page 972), the author would say that if juices were properly limed to begin with, it was not possible to "boil scum into the juice" with any heat that it was practicable to apply. Temperatures of upwards of 300° F. had been experimented on, with excellent results as far as the rapidity of settling and limpidity of juice were concerned, but with most disastrous results as to the sugar content, as great destruction of sugar took place in limed juices subjected to excessive heat, if only for a few minutes. As regards their own methods of using crystallizers, these appliances were new in Hawaii, and it was very possible that their methods would improve as they gained experience in the use of these machines. A change had been made since last crop, and the crystallizers were now being used for second sugars exclusively, with such success that the molasses driven off the second sugars in the centrifugals did not contain on an average more

than 34 per cent. of sugar, with a quotient of purity of about 40 per cent. Last year, when treating third sugars in the crystallizers, want of tank room compelled the wasting of molasses of this grade. This year this grade of molasses was boiled and run into storage tanks, where a certain amount of very low-grade sugar crystallised out, and, after drying, was melted and taken back into manufacture for conversion into # 1 sugar.

Regarding the pumping capacity now installed on this plantation, the figures given in the Paper were correct, the daily capacity of the 5 pumping-stations was 40,000,000 American gallons of water every 24 hours, lifted to an average height of 235 feet. This was now in course of being increased by another 10,000,000 gallons per 24 hours in two additional pumping-plants.

In reply to the remarks of Mr. John Laidlaw (page 973) respecting the expansive working of the mill engines in the Hawaiian Commercial and Sugar Company's factory, it could be pointed out that there was a limit in any sugar factory to the amount of exhaust steam which could be usefully employed in evaporation. If exhaust steam was in excess of this limit, it could only be got rid of by discharging out of doors at a considerable loss in fuel. This limit varied in different factories, and depended greatly on the kind of evaporator employed, less exhaust steam being required for concentrating the juice to syrup in a quadruple-effect apparatus, than in a double or triple-effect machine. There were usually so many large and small direct-acting pumps connected with a sugar works (all of which used direct steam throughout the full stroke), that wherever it was possible, automatic cut-off engines using steam expansively should be used, provided that the adoption of such machinery did not add to the complication or materially increase the duties of the men in charge.

Large engines in the United States were fitted with Corliss or other first-class automatic cut-off gear, and sold at a price which compared favourably with the price of slide-valve engines of equal size; indeed, it was doubtful if a slide-valve engine of such a size (30 inches by 60 inches) as used for driving the crushing plant in this factory, could be bought in the United States at this day, unless

(Mr. Williams.)

made to special order, which would involve new patterns, and thus considcrably increase the cost of such an engine. Theoretically, Mr. Laidlaw was correct in his statement; practically the modern tendency was to concentrate the power to be used in a sugar house in few cylinders, to use steam expansively, and to supplement the exhaust steam for evaporting purposes by direct steam admitted either to the exhaust mains or to the apparatus in operation.

Referring to the running of water-driven centrifugals, the author had not had the favourable experience in this direction that Mr. Laidlaw seemed to have obtained. He found that the fluctuations throughout a stroke in the pressure of the water delivered by duplex direct-acting pumps were anything but "slight"; and in the absence of an air-chamber of some kind, these fluctuations were passed on to the nozzles delivering water to the centrifugal machines, with the result that the speed could not be brought to the maximum so quickly, nor was the maximum velocity as great as when the air-chamber was used, the mean pressure of water at the pump being the same. In homely phrase "the proof of the pudding was in the eating thereof," and the Hawaiian Co.'s example in using a long air-chamber in connection with pressure-pumps had lately been followed by several factories working with water-driven centrifugals, with very beneficial results.

As regards the relative steam economy in water-driven, belt-driven, or electrically-driven centrifugal machines, it had been shown on neighbouring estates, one fitted up with 40-inch water-driven machines, and the other fitted with 40-inch belt-driven machines, the prime mover being an automatic cut-off engine in the latter case, while a duplex direct-acting steam-pump furnished the pressure-water in the former, that the belt-driven machines required somewhat less steam per horse-power. The water-driven machines, however, were much preferable on account of their simplicity, and the control the operator had over the speed of the machine up to its maximum velocity, a control which did not obtain with the belt-driven machine; the cost of upkeep was also much less with the water-driven machines, and these items discounted any considerations of small economies in steam, since no real object was attained if an

economy in one direction was offset by a loss in another. There was one point not touched upon by Mr. Laidlaw in his support of the water-driven centrifugal machine, and that was the waste of pressure-water which occurred between the time the machine had been brought to maximum speed and the time the machine was stopped. Now, in raw sugar work the centrifugal machine came up to the maximum velocity some little time before all the molasses was driven out of the sugar under operation, and in the Hawaiian Co.'s practice one nozzle was then shut off; but the nozzle that remained threw much more water on the wheel than would suffice to keep it at speed; if any attempt was made to economise by throttling the water, the pressure was reduced, consequently the spouting velocity of the jet leaving the nozzle was also reduced, and the speed of the centrifugal fell off, showing clearly that while the *weight* of water thrown on the wheel per unit of time should vary with the work to be done, the *velocity* of the jet should be constant. To the knowledge of the author no method had yet been devised to accomplish this desirable object. Another source of waste, which was common to the water-driven and belt-driven machines, was the loss of energy due to stopping the machine when its work on the sugar had been done. This appeared in the form of heat at the brakes in both instances, and in the water-driven machines necessitated the changing of the water in the supply-tank occasionally.

It seemed likely in the electrically-driven machine that this inherent energy in the rotating parts could be largely saved by reversing the current in the motor and using it as a generator, sending on the current so obtained to be used elsewhere. This probably could only be done at the expense of simplicity, and might not be very practical; but it showed possibilities of economy in advance of anything else now in use for the purpose of drying sugar.

In answer to the request of Mr. Howard Marsh (page 982), a sketch of the boiler arrangement was appended, Fig. 20, Plate 92, which would explain itself.

The author wished to acknowledge the cordial reception accorded to his Paper, and to thank those gentlemen who were kind enough

(Mr. Williams.)

to point out certain details which required elucidation. It was hoped that this short and necessarily imperfect description of the latest development of manufacturing processes in an important industry in which the British Colonies once occupied, and might occupy again, a leading position, might be of use not only to engineers but to all engaged in the Cane Sugar Industry.

GRADUATES' ASSOCIATION.

TWELVE MONTHS' REVISION OF A DRAWING OFFICE.*

By Mr. W. STANLEY BOTT, *Graduate*, of Newark.

The exigencies of modern manufacturing competition in the Engineering Trade have caused many firms to remove from London into the country, to enable them to build new works, arranged for more economical production. It is the object of this Paper to set forth some of the alterations made necessary in the Drawing Office system of one of these firms, by the improved conditions of manufacture, in the hope that it contains a few hints which may be useful to others about to undergo similar changes.

Before proceeding to describe the New Drawing Office arrangements, it will be advisable to give a short description of the methods in vogue before the move took place.

(1.) In the first place Drawings were made in various sizes up to Antiquarian, Double Elephant being the most usual.

(2.) Forgings were detailed "full size," but castings were very seldom drawn out in detail.

(3.) Drawings were numbered in connection with the number of the drawer in which they were kept; this number was never made use of for reference, and did not appear on shop tracings.

(4.) Tracings were used in the works, no blue-printing apparatus being available.

(5.) No pattern numbers appeared on any drawings, and very few pieces had names.

---

* This Paper, read on 9th December 1901, has been selected by the Council for publication.

(6.) Tracings sent outside the works were entered in a tracing book and given a number, the information for whom and to whom they were sent being also noted. This number had no relation to the drawing, and did not appear on it.

(7.) Certain machine parts, such as cutters and tools, etc., more particularly those which had to be obtained from the country, were given a detail number, one or more detail numbers being on one drawing.

(8.) Hand sketches were sometimes made, but no copy was kept in the office.

(9.) Drawings were kept in drawers numbered 1 to 79 under the class of machine to which they belonged, and the drawers were arranged against one wall of the drawing office from floor to ceiling.

In the New Works the Drawing Office has about two and a half times the floor area of the old, is lighted with a north light, the artificial light being two inverted arc lights supplemented by six incandescent lights.

In proceeding to revise the system just described, three points were seen to be imperative, namely: (1st) Every drawing must have a number and be known by that number: (2nd) All drawings must be made to standard sizes, and of as few sizes as possible; (3rd) A copy of every drawing must remain in the office, and be known as the Office Copy.

To consider the first of these points, the number, it was seen that a simple number would not do, because there were already in existence some hundreds of cutters, tools, etc., bearing detail numbers, and to avoid confusion it was decided to number the drawings in the following manner:—Below the drawing number proper a line was ruled, and underneath this a number was put to represent the year, thus $\frac{25}{0}$ represents $\frac{\text{Drawing 25.}}{\text{Year 1900}}$. Each year the top number will commence at 1, and the lower advance with the years. The author believes that a similar system to this is in use by Messrs. J. Simpson and Co., of Pimlico. This method was made easier at

starting, owing to the change taking place at the commencement of the century; and no doubt before three figures are introduced for the years a better method will be devised.

The second point is the size, and 36 inches by 24 inches was decided upon as being most convenient for general use, this size allowing a fair margin on a Double Elephant sheet; any smaller drawings are made 24 inches by 18 inches, 18 inches by 12 inches, or 12 inches by 9 inches, these sizes referring to border lines.

The third point is the Office Copy. The Office Copy drawing in all cases is a tracing, generally made on cloth, but sometimes tracing paper is used for a special job. All drawings referred to hereafter are Office Copy drawings. These have an additional border line and margin, at the right-hand end, the latter bearing the words "Office Copy" as well as the initials of tracer and of the draughtsman who checked the figures. This margin allows these particulars to be cut off any prints made from a tracing without departing from the regular sizes. Drawings are all numbered in the left-hand bottom corner and titled in the right-hand bottom corner; the number of the drawer in which it is to be put away appearing outside the border line, in the right-hand top corner. In the right-hand bottom corner also appears the Working or Shop Order No., and the number of sets required for that Working Number and the date, the quantities in all cases on a drawing being for one set only.

Having settled these three important points, the "Number," "Size," and "Office Copy," the next thing to consider was the method of keeping them. In the old office the drawers near the ceiling were impossible to get at without the aid of a pair of tall steps, which was very inconvenient. Therefore it was decided to keep all drawings in the new offices below the level of the tables. The method adopted was this:—

The drawers, Double Elephant size, were made up in cases of ten, each case being a complete thing in itself. Each case contains as nearly as possible all the drawings for one class of machinery, so that in the future, when the business expands, any case can be moved to another office if necessary without disturbing any other class, and

if one draughtsman is working on that class only, he can have the case under his table, and all the drawings immediately to hand; this will be an immense advantage as specialisation progresses. Each drawer in the centre of the front bears a label stating its contents; the top drawer of each block bears in large letters the group or class of machinery in that block.

Having described the sizes and form of drawings, the author will proceed to describe the method of making them. All drawings are made in pencil on a cheap cartridge paper and then traced; the drawing paper is used on both sides and ultimately is either used for envelopes or destroyed. The use of these envelopes is described later. When tracings have been checked, they become Office Copy drawings, and they are then blue-printed. These prints when in the shop are kept on boards, of which there are three sizes, specially constructed to allow the prints to be readily mounted or removed from them. Each Department has a supply of these boards.

The route of an Order through the Drawing Office into the Works will now be described. An Order, called a Production Order and bearing a Production Order Number, is received from the works manager, say for twelve complete machines of one sort and size. This production order is first divided into as many Shop or Working Order Numbers as is considered advisable, these numbers being noted on it. It is then passed on to the draughtsman taking the job in hand, who affixes his initials on it when the drawings are completed. When drawing casting details a 36-inch by 24-inch sheet is generally used, and each casting is allotted a certain space; these spaces are all of regular size, and whenever possible 9 inches by 6 inches. Of course large pieces require more than this size, and then a space twice or four times this is allowed, but all spaces are made so that if taken separately they will fold up to 9 inches by 6 inches.

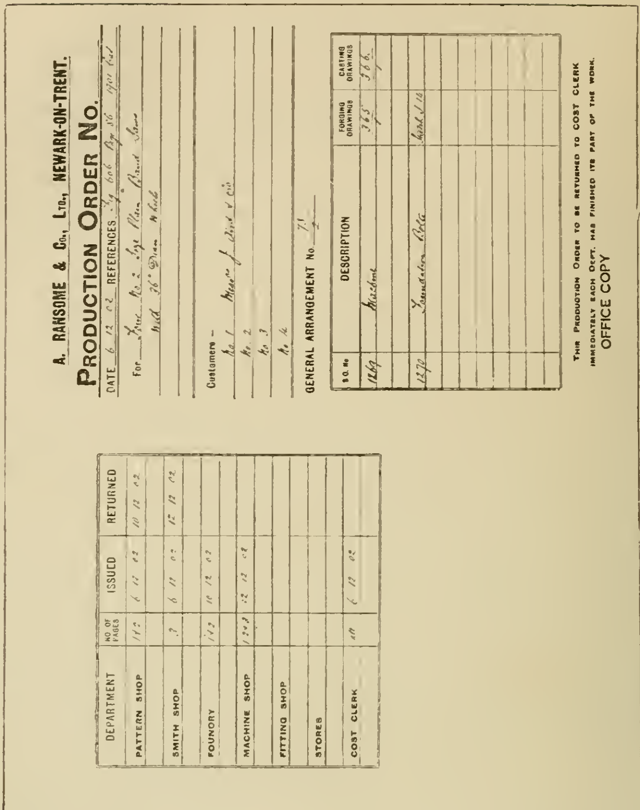
The objects aimed at in allotting each piece a certain regular space are:—(1st) to make each a complete drawing in itself with a name and a number, the number being the pattern number; (2nd) the compilation of a "Subject-Matter Pattern Index," which is effected by cutting up the blue prints when returned from the shops,

and filing in a 9-inch by 6-inch Card Index, which index the author thinks it would be impossible to obtain economically in any other manner. In a few years' time, no matter what sort of piece is required, it will be possible to tell if there is a suitable pattern for it in existence, by referring to this Subject-Matter Index; should only the number of a pattern be known, it is possible to find the number of the drawing on which it appears by referring to the Numerical Pattern Index, which is also kept on the card system. For any material required to be ordered out, and in this particular business few machines are made in which this is not the case, a purchase requisition is written in triplicate, one copy going to the purchase department, two copies being retained in the drawing office, one in the book itself, and the other is torn out and filed away under its shop order number, so that a record of all material ordered out for any one number is automatically collected, thus obviating serious delays likely to occur through parts, which should have been ordered out, having been overlooked when an order is repeated.

As the drawings are completed, the various parts required for each shop order are type-written in quadruplicate on specially ruled foolscap sheets, Fig. 1 (page 1008). The first of these copies remains in the drawing office, the second goes to the Cost Clerk, and the remaining two go into the shops. These detail shop orders form the foreman's authority for putting the work in hand in their respective departments. As there may be several shop order numbers for one production order, they are collected together in what is called the Production Order Cover, Fig. 2 (page 1008). The weight of each casting or forging, as it is made, is entered on the detail shop order sheet, and eventually, in the case of castings, on the Pattern Number Card Index, thus giving the drawing office useful information which hitherto had not been obtainable without reference to the cost-keeping book.

The detail production orders are found to be immensely useful in the various shops for checking over the quantities, etc., and more especially is this noticed in the machine shop, where they enable the foreman to keep all the parts on the move much more readily than if he had only the drawings to work from. A copy of each detail

Fig. 2.—Production Order Cover to hold the Shop Order Sheets.



Scale about ¼th originals.

Fig. 1.—Shop Order Sheet.

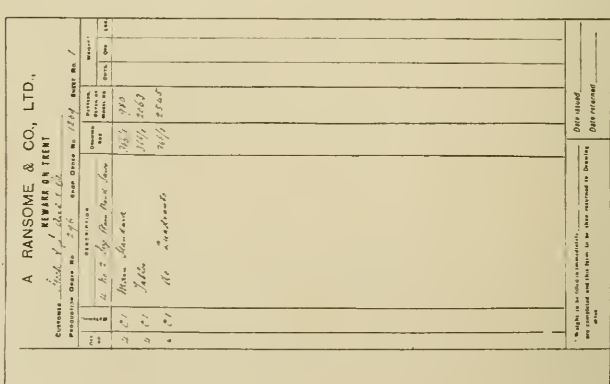


FIG. 3.—*Shop Order Form.*

SHOP ORDER No. 4780	DATE 6 12 02	In. O. No 1676
CUSTOMER J S Hall Newark		
DATE COMMENCED	DESCRIPTION OF ORDER.	DATE COMPLETED
	1 C.I. Bracket to their pattern 6715	
		D.O. Sign.
NOTES FOR FOUNDRY.		Man. Sign.
Be very careful to cast Hole with Flange in correct position		
DRAWINGS REQUIRED	Delivery urgent	

FIG. 6.—*Drawing Index Card.*

DRAWINGS SENT OUT FOR

DATE SENT OUT	TITLE OF DRAWING	WHO SENT TO	DRAW. NO.	DETAIL NO.	KIND OF COPY

ALPHABETICAL INDEX

A. RANSOME & Co., Ltd. Stanley Works, Newark.

FIG. 4.—*Shop Order Form.*

In O. No 1676	DATE 6. 12 02	SHOP ORDER No 4780
CUSTOMER J S Hall Newark		

Fit up one C I Bracket with
4 5/8 Bolts to templet

Templet to be returned with bracket

DELIVERY BY 10. 12. 02 — ORDER APPROVED

FITTING SHOP

FIG. 7.—*Drawing Requisition Form.*

DRAWING REQUISITION FORM.

To	Date	S.O. No.

DESCRIPTION OF DRAWING.	No

PLEASE SEND ABOVE DRAWING
TO ________ DPT. — Foreman

FIG. 5.—*Tool or Cutter Sheet.*

CUSTOMER.	S.O. No.	DATE.	Quantity.	T. MARK.

THIS NUMBER, DATE AND NAME TO BE STAMPED ON EVERY ARTICLE MADE FROM THIS DRAWING.	DETAIL No. DATE, / /190 A. RANSOME AND CO.,LTD., LONDON AND NEWARK, ENGLAND.	QUANTITY REQUIRED. S.O.

14″

Scale about ⅓rd originals.

order sheet is also sent to the stores, thus enabling the storekeepers to look out all the material required for it; this also gives them time to order anything they are short of. All these production orders are returned to the drawing office through the Cost Clerks' department, whose business it is to check the weights with the delivery notes they have already received from the stores. In this system a record of all material used for an order has to pass through the storekeeper's hands at one time or another.

The foremen of the various departments are instructed to make notes, on sheets provided in each Production Order for the purpose, of any improvements they can suggest for the cheapening of the work in their department, and also of any variations or delays which occur in the execution of the work. In this manner a history of the machine is gradually compiled, by means of which the repetition of mistakes is avoided in future orders, and besides which the information obtained is most useful in other ways.

With regard to repair parts and sundry orders which are always urgent, the order, just as received from a customer, is sent into the drawing office, and a Shop Order Form, Figs. 3 and 4 (page 1009), is issued to all departments concerned. This method gets the work put in hand very quickly, and as each department returns its order as soon as it has completed it, from any which are not returned it is immediately known where the job is stopped. A bright red label printed URGENT is fixed on breakdown and other very urgent repair orders.

Concerning the tools and cutters, etc., previously mentioned as bearing a detail number, a very great difficulty was at first experienced in the new works, owing to more than one detail number appearing on one drawing; and as one item might be used for a great number of customers, and to write the name of each customer on the drawing caused endless confusion, the following method has since been devised, which seems to meet all requirements. A Form, Fig. 5 (page 1009), was drawn out, and a quantity obtained on thin parchment paper, the printing on it being black. Each tool or cutter is now drawn on one of these forms to scale, and a record is kept in the table at the right-hand end of it, of the customer's

name, shop order number or inwards order number, quantity required, and the trade-mark; the record of the trade-mark is a very important item, because where a large quantity of tools is used, they cannot always be obtained from the same source, and in the case of complaints being received from a customer the name of manufacturer of goods can instantly be ascertained. As will be seen from Fig. 5, each article made from a detail number drawing bears its number, so that all a customer has to do when requiring a further supply is to quote the number and date on the tool itself. The detail number drawings bearing the tabular record of customers' names are filed away under their subject headings, and being all one size they form a card index.

A blue-print of each is also kept; these are filed away in numerical order, also in a card index. These two indexes thus enable any detail number drawing to be found immediately, no matter whether only the number or the name be known. With very little expense these records could be duplicated by blue-printing, and thus a stores reference index could be formed, which would also be a safeguard against fire. A 5-inch by 3-inch card index of customers' names is also kept in the office; for all machines and repairs, etc., ordered by them a white card is used; for tools, etc., ordered, a salmon-coloured card is used.

All drawings sent out are indexed under the name of customer they are sent out for; for this a blue card, Fig. 6 (page 1009), is used. There is also a machine index kept, all machines made being indexed under the class and size; for this a white card is used. All drawings received in the office are numbered and filed away in pigeon-holes. All samples of work done on the machines manufactured are numbered, recorded, and kept in a sample room which is in charge of one of the junior draughtsmen. All catalogues received are kept in the drawing office, being filed away according to their size, the stiff-covered ones by themselves, and the limp-covered ones in cloth-covered pamphlet boxes. Two indexes are kept of these, one of makers' names, and one subject-matter index.

Sketches are made in numbered sketch books, each page also being numbered in duplicate; the sketch is duplicated by carbon

paper, and being already numbered no other reference is needed. Specifications of shafting, belting, piping, etc., are written in copying pencil on forms printed in copying ink, and press-copied in a book in the ordinary way. Complete specifications are compiled for each new machine made, by the draughtsman in charge of the job; in this manner any alterations in design are recorded, thus helping to avoid mistakes occuring when tenders are being sent in, and which, when they do occur, are apt to prove very costly.

Each department in the works is supplied with a pad of Drawing Requisition Forms, Fig. 7 (page 1009), one of which forms is filled up and forwarded to the drawing office when a drawing is required. This obviates the necessity of a foreman having to hunt round for a piece of paper on which to write his requests, or perhaps sending a verbal message which is translated into something quite different before reaching the office. One notable deficiency still is the impossibility of obtaining a rubber stamp to make a sufficiently opaque impression on a tracing for blue-printing purposes. If some ink or pad could be found which would make this possible it would be a great boon. The detail shop orders are all type-written, as it is quite possible to obtain four good copies at once on a suitable machine, and it is found that type-written orders are fully appreciated in the works. Photo prints are made by means of an electric copier, which is constructed of a 24-inch diameter glass cylinder around which the tracings are pressed, and a strong arc lamp which is automatically lowered through the cylinder.

In conclusion, the author would like to thank the following gentlemen for their kindness in explaining to him the systems in use in their respective offices, the information obtained having been most useful: Mr. Jones, of the Brush Electrical Engineering Co., Mr. Jennings, of the Sturtevant Engineering Co., and Mr. Burdon, of Messrs. J. Simpson and Co.

The Paper is illustrated by 7 Figs. in the letterpress.

GRADUATES' ASSOCIATION.

WESTON-TWERTON BRIDGE UNDERTAKING.*

By Mr. HENRY H. MOGG, *Graduate*, of Bath.

Introduction.—It may not be generally known that the bridges in Bath, with two exceptions, namely, the Old and the Midland, the former owned by the Corporation, and the latter by the Midland Railway Co., are toll or tied bridges. These bridges, from time to time, have been erected by various companies or syndicates as going concerns, each foot-passenger paying a $\frac{1}{2}d.$ for passing over, horses, carriages, bicycles, etc., paying on a graduated scale varying from a penny to three pence per vehicle; it can thus be readily seen that the Avon for about two miles on the east and west side of Bath is practically fortified, so that no one, unless he has the required money in his pocket, can cross the river except by walking over the two above-named bridges, which are both situated in the centre of the town.

All these bridge companies are thriving concerns, paying excellent dividends; it is believed that one or two are giving as much as 30 per cent. or more on the original shares.

It therefore occurred to the author, in conjunction with one or two others, that a good future for such a bridge was to be found in spanning the river between Weston and Twerton, two growing suburbs of Bath, one with a population of over 7,000, the other numbering something about 11,000. After careful consideration a site was decided upon, which was just between the Weston Midland Station and the Great Western Railway in Twerton. Passengers desiring to pass from one place to another were accommodated at that

* This Paper, read on 14th April 1902, has been selected by the Council for publication.

time by a large ferry boat propelled across the stream by means of a ratchet arrangement, crank and handle, worked by a boy; a long chain passed through the ratchet-wheels, the ends of which were securely fastened to either bank, the boat being worked backwards and forwards at a fairly rapid speed, over a space of about 160 feet.

In March 1900, instructions were given to the author to make a sectional drawing of the river at this point, survey the land on both sides, and to proceed with all necessary designs so as to produce the probable cost of the undertaking; this was done, and a bore-hole driven on the Twerton side so as to test the nature of the ground for foundations. From various causes, such as having to send drawings of the scheme to the various public bodies interested for their sanction, &c., the work could not be actually started until about the second week in August in the same year; it was then seen that the project would have to be carried through as rapidly as possible, because in the months of December and January the Avon frequently overflows, passing down the valley with tremendous rapidity.

Tenders were sent out for the whole of the work, and Messrs. David Rowell and Co., of London and Darlaston, secured the steel portion, whilst Messrs. Mould of Bath, undertook the coffer-damming and masonry.

Coffer-Dam.—On the Twerton side a coffer-dam had to be constructed, inside which the bridge pier, wing walls, and toll-house, were built, Plate 93. The river at this point is about 25 feet deep at full water, so that a fairly strong dam was required to stand the necessary pressure; a cloth mill also, whose race for the turbines is on the Twerton side just below the bridge, causes a rapid current in the stream.

The strata through which the piles were driven consisted of soft mud, vegetable deposit, overlaying a bed of strong gravel and sand, and lastly stiff, blue clay. The first thing which had to be borne in mind was that this coffer-dam should be constructed as cheaply as possible, due regard being paid to safety; all money spent in this direction was actually lost, as the coffer-dam was removed when the masonry had got to a height beyond the water line. Timbers were

driven 6 feet apart, 12 inches by 9 inches as space piles, with 1-inch tie-rods of wrought-iron passing through them; large cast-iron washers were fixed on the outside and the same on the inside, about 6 inches square, and kept together by means of the usual hexagon nuts. Planks 9 inches by 3 inches were securely spiked to these outside timbers, and strutted by strong baulks of wood to the inside sheet piles of dam; 18 inches space was left for the puddle, which consisted of stiff, blue clay, which had been passed through the pug-mill of a brick-yard in the immediate vicinity of the works, and was cheap and easily procurable; this when well rammed and consolidated together formed an excellent puddle. The inside planking dimensions were 3 inches by 9 inches; these were held in place by three rows of longitudinal strips 12 inches by 6 inches, these again being heavily strutted by 12 inches by 6 inches timbers placed right across the working, the soil opposite to the coffer-dam being well timbered to guard against possibility of any sudden collapse or slip of earth.

The coffer-dam when completed was practically water-tight, water here and there percolating through the bottom sheets; the bottom of the working was drained towards a sump in which the suction-pipe of a pump was kept, so that any excess of water could be easily pumped out. Platforms and stagings were formed within the dam so as to facilitate the removing of the soil, but when at a fairly low depth, the earth, etc., was drawn up in barrows by means of blocks and falls, and wheeled straight into position to form the embankment on the Twerton side of the river, which was composed almost entirely of the excavated material. During the carrying out of this portion of the works an old stone drain was struck, which carried down, even at that time of year (August) a large volume of water; this had to be diverted and carried into the river before further excavation could be proceeded with in the coffer-dam.

Concrete.—The whole of the concrete used throughout the works was formed of one part by measure of Portland cement of the best quality, ground extremely fine and weighing not less than 112 lbs. to the imperial bushel, two parts of clean sharp sand and four parts of broken stone, no single stone weighing more than half a

pound, and no lime or soft stone of any description was to be used. The whole was turned over twice upon a wooden platform in a dry state, and twice after water had been applied by means of a spreader; lastly, the concrete was placed in position within 15 minutes after being mixed. All gaugings were supervised by a responsible person, independent of the contractor. The concrete was wheeled direct from the gauging platform to the mouth of excavation and tipped over, the whole being raked over smooth.

On the Weston side of the bridge no coffer-dam was constructed. As previously stated the pier and wing walls had to be placed 15 feet back from the river; more difficulty however was experienced here through the water, for after the excavations had been sunk some 12 or 13 feet, water began oozing through, necessitating the constant use of pumps so as to allow the men to work.

Masonry.—All work above the surface was constructed of what is termed, in the neighbourhood of Bath, rough shoddy stone, edged and cornered by freestone, as were also the dwarf and main columns at each end of the bridge. The masonry on the Weston side consists of a pier, two wing walls well battered back; two heavy pennant stones being placed on the top of pier as packing stones for the bridge. In Twerton a toll-house was constructed, a pier and one wing wall, identical to that on the Weston.

Embankments.—The embankment in Weston has a gradient of one in ten, so as to give the desired rise to the bridge. The approach leading thereto had also to be raised up 4 to 5 feet, so as to keep it above flood-level. As the embankment and road would form a dam when the river overflowed its banks, it had to be made of great strength; gas lime was procured from the gas-works and mixed with the excavated soil, the whole piled together and in a short time formed into a hard mass like concrete. This has made a very solid embankment, the only objection being that after a frost the lime seems to work up to the surface, in spite of the macadamized road. In Twerton the embankment is chiefly composed of the soil extracted from the excavations on this side, the remainder being made up of old clinkers and rubbish, the surface being macadamized and gravelled as on the opposite shore. The bottom wall of the cottage

is used as a retainer, and was built up of large-sized rough stones well cemented together, the three outer walls which are 18 inches in thickness forming a bond or strut for the retaining wall. The bottom portion of the toll-house is used as a kitchen and wash room.

Steel Work.—The bridge is of the lattice bow girder type, constructed throughout of the best mild steel. The leading dimensions are as follows:—Span 125 feet in the clear, 6 feet wide. The end bays have struts and braces 6 inches by 3 inches by $\frac{3}{8}$ T and 6 inches by $\frac{1}{2}$ inch tension bars, and No. 7 rivets at end; the second bay struts and braces 5 inches by 3 inches by $\frac{3}{8}$ inch T and 5 inches by $\frac{1}{2}$ inch tension bars, No. 5 rivets at ends. The third bay struts and braces 5 inches by 3 inches by $\frac{3}{8}$ inch T and 5 inches by $\frac{1}{2}$ inch tension bars, No. 5 rivets. All other bays have 5 inches by 3 inches by $\frac{3}{8}$ inch T struts and braces and 5 inches by $\frac{3}{8}$ inch T, tension bars, and No. 4 rivets at each end. The top and bottom booms are made of 10 inches by $\frac{3}{8}$ inch plate between vertical flanges and main angles. The main angles are $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inches by $\frac{3}{8}$ inch, the flange plates being 12 inches by $\frac{3}{8}$ inch. Top bracings 5 inches by 3 inches by $\frac{3}{8}$ inch T at every vertical between the second vertical from each end. The wind bracings under bridge 3 inches by 3 inches by $\frac{3}{8}$ inch L, which are riveted to the flange plates of girders. The floor of the bridge, consisting of planks of the best Archangel timber, 3 inches in thickness and carried on 4 inches by 4 inches by $\frac{3}{8}$ T, bolted down by means of cup-headed bolts and hexagon nuts. All holes were drilled, as no punching was allowed throughout the work. Before deciding on the type of a bridge to be constructed, not only should utility, strength, cost and appearance be considered, but a very important factor is the erection; so much so indeed that in some cases facility in transmission and erection may overrule all other considerations. Each method of erection must depend upon the situation and other circumstances; no two jobs will probably work out alike, and what might be a success in one place might mean absolute failure in another. After careful consideration it was thought that there was no better type of bridge, barring a steel rope (which was prohibited), to lend itself to all the conditions required of it, viz.:—First cost to be low, of easy transit, and of great

facility in erection. The bridge was built at Darlaston in Staffordshire, and, after being tested and passed, was taken to pieces and sent by rail to Bath, and from thence to the site on low trolleys.

Erection.—In girder-bridge work there are practically four systems of erection, namely, by means of stages, by building out, by pushing or rolling over of the main girders, and lastly by floating, either in part or whole. This last method was adopted with the bridge in question. The bridge being erected on the Weston shore, the bottom girders were laid on heavy baulks of timber placed longitudinally, the surface being covered with sheet iron; on this the whole bridge was riveted up, the last bay when placed in position coming within about 30 feet of the edge of the bank, this being allowed for the traffic passing up and down the towing-path. When the bridge was riveted up, complete rollers, consisting of cast-iron flanged pipes, were placed underneath the bridge about 9 feet apart, these rollers running on the before-mentioned longitudinal lengths of timber, the rollers coming in direct contact with the sheet-iron; the flanges of the pipes protruded beyond the edge of the timbers on either side, thus preventing them running askew, or in other words keeping them parallel. Two double-purchase crabs or winches were placed behind the bridge, as the land on this side falls away towards the river; two windlasses were also fixed on the opposite shore, one immediately opposite the bridge, the other being mounted half-way down the embankment at the back of pier. Great care had to be exercised that, when the bridge first took its impulse from the crabs on the Twerton side that it did not run with too great a velocity, having a dead weight in the bridge of about 35 tons; the back crabs were used as drags, besides which chocks were kept in readiness for blocking the rollers.

A flat-bottomed barge, 12 feet wide by 30 long, was brought stern on to the Weston bank, two steel hawsers being passed from one shore to the other, one on each side of the boat; these ran through wheel clutches so as to prevent the current, which is rapid at this point, from carrying the barge when in mid-stream out of its course. As the deck of the boat was some 20 feet below the bottom girders of the bridge when standing overhanging the bank, two piles or

pyramids, composed of old railway sleepers, had to be placed crossways in the barge, so as to take the Twerton end of the bridge from the rollers.

The bridge being started on its course, all went well until the front portion reached the edge of the bank and began overlapping the stream, but had not yet dropped on to the first pile of timbers in the barge which were prepared to take the weight; the mass being too heavy for the soil composing the bank, the earth began tearing away, and the bridge had to be backed by means of the crabs on the Weston side, whilst the bank was strutted and shored up. The bridge was then again rolled forward and placed on the first pile of timbers in the barge, and from thence to the second pile, and so on; the forward steel rollers, which had so far assisted in propelling the bridge, were then removed, the back rollers only being left; the barge was then pulled across the stream by means of the winches on the Twerton side. As there was deep water here and a low bank, no great difficulty was found in landing. Hydraulic jacks were placed under the bridge at the Twerton end of the structure, these jacks being also provided with a horizontal screw movement; the bridge was lifted and then worked in a longitudinal direction on to packings prepared for its reception on the bank. The packings, which consisted of railway sleepers, were piled alongside the masonry piers on both sides of the river, the bridge being lifted by means of the jacks, inch by inch, the sleepers being slipped under as it rose; these temporary wooden piers were carried up until they reached to a height of about 3 or 4 inches above the permanent masonry. Two iron rails were then placed from the timber piles on which the bridge rested to the stone pier, this being done both on the Weston and Twerton side; the rails being well greased, the bridge was slid gradually on to the bed-stones by means of handspikes and jacks. The whole operation of floating and lifting the bridge took about eighteen hours; only one steam barge was delayed for about an hour, in consequence of being unable to drop her funnel so as to pass under.

The erection of bridges by means of floating undoubtedly presents great advantages, admitting as it does large girders being constructed

complete in some convenient and safe place, and of their being removed and fixed into position during the course of a very short period. The bridge was completed by the 15th December 1900, having taken just three months to build; it was fortunate that its construction and erection were performed so quickly, for early in January 1901 one of the highest floods ever known in the district took place. The Contractors, who had not yet removed all their plant and timber, suffered heavily thereby.

The Paper is illustrated by Plate 93.

MEMOIRS.

Sir Frederick Augustus Abel, Bart., G.C.V.O., K.C.B., was born at Woolwich on 17th of July 1827, being the son of the late Mr. Johann Frederick Abel, of that town. Electing to be a chemist, he commenced his studies in 1844 at the Royal Polytechnic Institution, and in the following year entered the Royal College of Chemistry, which had just then been founded, with a temporary laboratory in George Street, Hanover Square. In 1846 he became assistant to Professor Hoffman, under whose direction the College was founded. After five years in this position, he was appointed to succeed Faraday as Professor of Chemistry at the Royal Military Academy, a post he held until 1854, when he was appointed Chemist to the War Office. In this position he remained until 1891, as adviser of the department in all matters affecting ammunition and explosives. During the last three years of that period he was also President of the Explosives Committee. In 1888 the Government appointed a Select Committee to examine the various kinds of smokeless powder in existence, and to report which of them was best adapted to the requirements of the Service. Ultimately Sir Frederick with Professor Dewar, who was also a member of the committee, patented the substance now known as cordite, and since adopted in the Navy and Army. Litigation ensued with the view of nullifying the patent, but he won the case. In conjunction with Sir Andrew Noble he carried out investigations into the processes attendant on the firing of black powder. To the theory of detonation he made important contributions, and the construction of electrical and other fuses also engaged his attention. In 1879 he was appointed a member of the Royal Commission on Accidents in Mines, his knowledge of blasting powders being of great service. He rendered useful service on the subject of the flash-point of petroleum, the result being the legislation in 1868 of his open-test apparatus; and later, when it proved subject to

manipulation, the close-test instrument was designed and legalised in 1879, which has since continued the standard.

In 1883 he was elected an Honorary Member of this Institution, having in 1881 undertaken for the Research Committee on the Hardening, &c., of Steel,* experiments on the condition in which carbon exists in steel. A second Report was presented in 1883 (page 56), and the final Report in 1885 (page 30). The actual carrying out of these experiments was performed by his colleague in the chemical department of Woolwich Arsenal, Mr. W. H. Deering. He retired from his appointment at the War Office in 1888, having become in 1887 Organising Secretary of the Imperial Institute, which position he held until 1900, and was still working as Honorary Secretary when his death took place. He was made a Companion of the Bath in 1877, received the honour of Knighthood in 1883, promoted to the rank of Knight Commander of the Bath in 1891, and created a Baronet in 1893, after the opening of the Imperial Institute, and in 1901 he received the honour of the Grand Cross of the Royal Victorian Order. He was a Fellow of the Royal Society, D.C.L. of Oxford, and D.Sc. of Cambridge. He had been President of the British Association, the Iron and Steel Institute, the Chemical Society, the Institute of Chemistry, the Society of Chemical Industry, the Institution of Electrical Engineers, and had also been Chairman of the Society of Arts. He held the Albert, the Royal, the Telford, and the Bessemer Medals, and had published several books, chiefly associated with explosives. His death occurred suddenly at his residence in Whitehall Court, London, on 6th September 1902, at the age of seventy-five.

Henry Ainley was born in Oldham on 12th September 1835. At the age of fifteen he commenced to work at the Hartford Engineering and Machine Works of Messrs. Platt Brothers and Co., Oldham, and after a course of training in the drawing office, he spent some years in the fitting shops as a mechanic, and in the erection of machinery in cotton mills. He then returned to the drawing office,

---

* Proceedings 1881, page 696.

where the designing and laying out of mills and the planning of the arrangement of machinery were carried on, and for many years he had charge of that department. His death took place at his residence in Oldham, after a very brief illness, on 6th October 1902, at the age of sixty-seven. He became a Member of this Institution in 1893.

PETER BROTHERHOOD was born at Maidenhead on 22nd April 1838, being the son of the late Mr. Rowland Brotherhood, railway contractor, of Chippenham, Wiltshire. Having received a good elementary education, he afterwards passed through the engineering course in the department of Applied Science at King's College, London. At the age of nineteen he entered his father's works for a short period, proceeding in the following year to the locomotive works of the Great Western Railway at Swindon. When twenty-one years of age, he returned to his father's works to superintend the designing and construction of locomotives and other railway plant and material. He next went to the drawing office of Messrs. Maudslay, Sons and Field, at Lambeth, where he obtained a knowledge of the best practice in marine engineering. In 1867 he commenced business on his own account. At the outset he became a partner in the engineering works at Compton Street, Goswell Road, London, with Mr. H. Kitto, who, however, soon afterwards retired. Later Mr. Hardingham became associated with him, and continued until 1878, when Mr. G. B. Oughterson joined him as general manager—a position he held until 1897. But from first to last Mr. Brotherhood was the main element in the success of his works, a fact due to his skill as a mechanic and his ingenuity as an inventive designer. In 1872 he introduced his special three-cylinder steam-engine,* which was first exhibited at the Agricultural Hall, and came speedily into use. The distinctive feature of the design was that the three cylinders, which were fitted with single-acting pistons, were arranged at angles of 120° around a central chamber; the three connecting-rods were attached at one end to the inner side of their respective pistons, and at the other end to a common single crank

* Proceedings 1874, page 173.

by a pair of guard rings at front and back. As the pressure was always at the back of the pistons, it kept the rods up to their seats on the crank-pin.

This engine, exhibited for a second time at the Vienna Exhibition of 1873, created a considerable amount of interest. Shortly afterwards the superintendent of the Royal Laboratory at Woolwich Arsenal, on seeing the engine, was greatly impressed with its adaptability for driving torpedoes because of its compactness, and of its suitability for such a confined cylindrical vessel, with the shaft placed in the centre line. The Whitehead torpedo had up to this time been driven by a compound oscillating engine, using air as a prime mover; but the success of the first Brotherhood engine using compressed air resulted in its ready and almost universal application for torpedoes.* The engine was also applied for driving centrifugal fans direct, for running forced-draught fans direct, and for hydraulic work.† The development of the engine alone necessitated larger premises, and the works at Belvedere Road, Westminster, were laid out in 1881, being considerably enlarged in 1896. He had previously to this designed a compressor for the Whitehead torpedo with two air-cylinders instead of four, and in other ways saved considerable space. In the introduction of the modern high-speed engine, which ultimately displaced his three-cylinder steam engine, he had some share, and his first ordinary double-acting engine was fitted direct-coupled to the dynamos in the late Queen's yacht, the "Victoria and Albert." He had, what might be termed, a mechanical instinct. He could evolve from his experience, even in the earlier days, sizes and capacities without any formulæ or calculations, being seldom, if ever, wrong in his results. For some time he had been in indifferent health, but his death came somewhat suddenly, due to internal hemorrhage, at his residence in Hyde Park Gardens, London, on 13th October 1902, in his sixty-fifth year. He became a Member of this Institution in 1874; and was also a Member of the Institution of Civil Engineers.

---

* Proceedings 1874, page 224.

† Do. 1887, page 73.

James Brown was born in Bury, Lancashire, on 21st June 1850. Having been educated at private schools, he served three years' apprenticeship at the locomotive works of the Waterford and Limerick Railway. This was followed by two years with Messrs. W. Sharples, engineers, of Ramsbottom, Lancashire, and another two years with Messrs. Bentley and Jackson, engineers, of Bury. During this period, 1866–1870, he also attended technical classes at the Ramsbottom Science and Art School. On the completion of his apprenticeship, he worked for one year as engineer with Messrs. Lamport and Holt, Brazilian Steamship Co., of Liverpool, and then from 1871 to 1873 with Messrs. Hick, Hargreaves and Co., of Bolton. In the latter year he went to Messrs. Laird Brothers, of Birkenhead, with whom he worked as engineer for three years. After having been in the employment of various firms, he became in 1887 an inspector for the Pearson and Knowles Coal and Iron Co., where he had 120 boilers in his charge. With this firm he remained four years, and then went as boiler inspector for the British Steam Users' Society, Manchester. Early in 1902 he started on his own account as consulting engineer at Longton, Staffordshire. His death took took place in Birmingham, on 22nd November 1902, in his fifty-third year. He became an Associate Member of this Institution in 1902.

James Gregson Chapman was born in Liverpool on 1st June 1832. In 1848 he commenced an apprenticeship under Mr. Thomas Hunt at the locomotive shops of the London and North Western Railway, at Preston, after which, in 1850, he went to Mr. Joseph Clayton's Soho Foundry, Preston, for one year; and finally from 1851 to 1855 he completed his term in the works of Messrs. Fawcett, Preston and Co., of Liverpool. He was then employed by them as draughtsman, and subsequently represented them abroad. In 1859 he established himself as a consulting engineer, and in conjunction with Messrs. Fawcett, Preston and Co., and other firms, he designed and erected sugar factories, sugar machinery, iron warehouses, narrow-gauge railways, bridges, marine engines and boilers in the English and Spanish West Indies, in Spain, Egypt, Java,

Peru, Mexico, Central America, Buenos Aires, Brazil, and other countries. Since 1872 he had been a partner in the firm of Messrs. Fawcett, Preston and Co., during which time he had been constantly engaged in the designing and manufacturing of sugar machinery, marine engines and boilers, hydraulic presses and other machinery. On the conversion of the firm into a company in 1888, he joined the board of directors, and remained a director until his death, which took place at his residence in London, on 20th October 1902, in his seventy-first year. He became a Member of this Institution in 1878.

George Francis Gregory was born in London on 17th March 1856, being the eldest son of the late Mr. G. B. Gregory, for many years Member of Parliament for East Sussex, and a leading London solicitor. He was educated at Eton and Cambridge, and was called to the bar by the Inner Temple in 1882 and joined the South-Eastern Circuit. His tastes were largely in the direction of civil and mechanical engineering, and he became an Associate of this Institution in 1889, taking great interest and pleasure in the Meetings and visits. He was a Justice of the Peace for Sussex, and took a prominent part in all local affairs. He had been in ill-health for some few months prior to his death, which took place on 9th September 1902, at his residence Boarzell, Hurst Green, Sussex, at the age of forty-six.

John Imray was the son of the Rev. John Imray, of Longside, Aberdeenshire, and was born at Peterhead on 12th August 1820. He received his first education at the village school of Longside, and when thirteen years of age proceeded to Aberdeen to attend the Grammar School there, and was soon successful in obtaining a scholarship at Marischal College, Aberdeen, where he gained the mathematical scholarship and subsequently his degree of M.A. In 1837 he proceeded to London, and succeeded in obtaining an entry into the firm of Messrs. Maudslay, Sons and Field as a pupil, commencing work there in May 1838. Whilst with this firm he assisted Mr. Field in preparing the drawings for the arrangement of a marine-engine known as the double-cylinder engine, which was considered a great

advance at that time. During the latter part of his time with Messrs. Maudslay he was employed in his leisure hours by Dr. Reid in preparing drawings for the warming and ventilating of the new Houses of Parliament, &c. At the expiration of his apprenticeship at Messrs. Maudslay's, in May 1842, he left that firm and began work in the Ventilation Office of the new Houses of Parliament, where he remained until 1850, assisting Dr. Reid in most of his work and being specially engaged in arranging the ventilating apparatus in the royal yacht called the "Royal George," and also in preparing the rooms of Buckingham Palace for the great Balls, and the Opera House for the late Queen's State visits. About the end of the year 1845 matters were at a standstill at the new Houses of Parliament, as the architect and ventilator could not agree; and Mr. Imray, having a considerable amount of spare time on his hands, was employed to a large extent in making surveys for railways during the railway mania of that period. He took levels for a line of railway in Essex and for the line between Rugby and Manchester, often having great difficulty in carrying out his investigations owing to the strong opposition met with in many country places. In 1850 he joined Mr. Arthur Collinge in partnership in an engineering business at Lambeth, and during 1854 constructed a large number of engines for Messrs. Maudslay and Messrs. Penn for war vessels and gunboats required at that time. In 1857 he purchased his partner's interest in the business, carrying it on on his own account until 1867. In the 1862 Exhibition he exhibited several steam-engines and also a steam-hammer which he had invented. In 1864 he commenced to act professionally as adviser and expert in law cases connected with patents and machinery, and about this time he wrote a treatise on practical mechanics and the steam-engine, which formed part of Orr's circle of the Sciences.

In 1867 he gave up his engineering business at Lambeth, and started as consulting engineer and patent agent in Great George Street, Westminster, and was then employed to repair the Lambeth Suspension Bridge. He also gave certain suggestions to Mr. W. H. Barlow in designing the great St. Pancras Station. In conjunction with Mr. R. Richardson he prepared plans for a canal to bring a

supply of sea water to London and for the formation of a light overhead railway from Islington to the City. For some time he took the leading part in an Institute called The Inventor's Institute, and acted as editor of the "Scientific Review." In 1871 he joined Mr. Abel (brother of the late Sir Frederick Abel, Bart.) in partnership as consulting engineers and patent agents, in which business he took a very active part until a fortnight before his death. He contributed a Paper to this Institution in 1874 (page 281) on a Helical Pump, which had been evolved as the result of experiments with Mr. Matthew Boulton in 1867. For many years he was employed as an expert in most cases of patent litigation, and among the principal cases may be mentioned the Telephone actions, the Otto gas-engine actions, the Westinghouse brake actions, railway signalling actions, and the Welsbach gas lighting actions. In 1882 the Institute of Patent Agents was formed, when he was elected Vice-President and in the succeeding year was elected President, devoting a considerable time to the successful formation of this Institute and the obtaining of its Royal Charter. He was also a Member of the Institution of Civil Engineers, and of the Royal Institution. He took a keen interest in local affairs, and for six years occupied a seat on the Finchley Local Board, and gave considerable professional aid in the very extensive works for the sewerage of that parish. When the County Council Act came into force, he was elected by a considerable majority as one of the two representatives of Finchley for the first County Council of Middlesex, and was returned for the second County Council without opposition. When the Borough Council came into force, he was returned as one of the first members of the Borough Council for Holborn. His death took place at his residence in Mecklenburgh Square, London, on 29th September 1902, at the age of eighty-two. He became a Member of this Institution in 1877.

ALEXANDER SINCLAIR MACPHERSON was born in Aberdeen on 23rd November 1835. Having been educated in Kirkcaldy, his parents sent him to Leeds in 1849 with a letter of introduction to Mr. (afterwards Sir) Peter Fairbairn, of Wellington Foundry, who

took him into his works. He progressed so well that he was admitted into partnership at the age of forty-eight. Meanwhile he had paid frequent visits to Scotland and the Continent on behalf of the firm, but of late years he did not travel much, his energies being devoted to the management of the works. The branch of engineering carried on at Wellington Foundry has been principally the production of textile machinery, and although there is also a large department for making machine tools such as are used for railway and ordnance works, &c., it was to the perfecting of the machinery used in the preparation and spinning of flax, hemp, jute, and similar fibres, that he directed his attention, and in connection with which he effected many improvements. His advice and opinion were much valued in the Dundee jute circles, and he was instrumental in establishing a large connection throughout the jute trade in Calcutta. In 1900 the business of Messrs. Fairbairn, Naylor, Macpherson and Co., was amalgamated with that of three other machine-making concerns, and became known as the Fairbairn Macpherson branch of Messrs. Fairbairn, Lawson, Combe, Barbour. Of this branch he was managing director. He was one of the District Commissioners of Property and Income Tax for Leeds. His death took place at his residence in Harrogate, from heart failure, on 30th September 1902, in his sixty-seventh year. He became a Member of this Institution in 1884.

Edgar Harrisson Messer was born at Reading on 11th September 1867, and was educated at Sidcot School, Somerset, and Bootham School at York. In 1885 he was apprenticed to Messrs. W. and J. Player, engineers, of Birmingham, and was employed there for three years in the fitting shops, and for one year in the drawing office. In 1889 he proceeded to South Africa, and was employed for two years as an erector in various mines. Afterwards he was appointed engineer-in-charge of the New Primrose Gold Mining Co.'s stamp mill, cyanide plant, and hoisting works. At the beginning of 1893 he became head draughtsman to Mr. S. B. Connor, consulting engineer to the Consolidated Gold Fields of South Africa. With the exception of a visit to the Australian Gold Fields, extending over

nine months (1896–7), he continued his connection with the Consolidated Gold Fields of South Africa, as assistant mechanical engineer under Mr. J. B. Pitchford, and later under Mr. H. C. Behr, whose appreciation of his services both gentlemen were proud to acknowledge. Severing his long connection with the company in June 1902, he joined the British Engineers' Alliance, as chief engineer, where his thorough knowledge of every detail connected with the mining industry promised him a brilliant future. His career of usefulness was however cut short very soon after joining the Alliance. Contracting a severe cold which developed into double pneumonia, he died in Johannesburg, on 12th August 1902, in his thirty-fifth year. He became an Associate Member of this Institution in 1895.

CHARLES HENRY MOBERLY was born in Odessa on 15th September 1833. His father was a merchant in that town until the Crimean War, when he moved to London and became a member of Lloyds. When eight years of age he went to school at Dresden, and in 1849 came to King's College, London, to receive his engineering education. In 1852 he left college, and became a pupil at the works of Messrs. J. and G. Rennie, of London, during which period he acted for a year as fourth engineer on a steamer. At the end of 1856 he became engineer to the River Steamers Co. of Cork, and held that position for two years, at the close of which he was appointed inspector of the construction of three light-draught steamers for the River Volga. These steamers had the peculiarity that, as they were much longer than the locks through which they had to pass on the way to their destination, they were made capable of being divided up into sections while afloat, each piece being then taken through the locks separately.* He made all the arrangements for the transport, and took the steamers out himself in the spring of 1859. He remained on the Volga as assistant to the chief engineer of the Volga Steam Navigation Co., and as manager of their passenger steamers until the end of 1865, when he returned to London to take up the position of

* Transactions, Institution of Civil Engineers of Ireland, 1862, vol. vii, page 1.

manager of the Erith Works of Messrs. Easton, Amos and Anderson. In 1878 he became a partner, and on the conversion of the firm into a company, he became one of the directors, until his retirement at the end of 1892. During this period he was closely connected with the varied work of the firm, not only making many of the calculations and designs, but organising the manufacture in the shops, an operation of no small magnitude considering the great variety of work turned out. The special branch in which his talents came conspicuously to the front was in wrought-iron and steel plate work. He carried out many experiments on riveted joints in the early days of the use of steel for constructive work, and contributed a Paper on the subject to the Institution of Civil Engineers,* for which he received a Telford Premium. On his retirement from the company, he commenced to practice as a consulting engineer, in which capacity his intimate acquaintance with the technicalities of the Russian and German languages was turned to good account. In 1895 (Proceedings, page 658), he translated and abstracted for this Institution the report on "The Results of Preliminary Tests of the Strength of Copper," by Professor A. Martens, Principal of the Royal Technical Experimental Works, Berlin. He was for many years past a constant attendant at the Meetings. After an illness of some duration, his death occurred at his residence at Blackheath, London, on 3rd September 1902, in his sixty-ninth year. He became a Member of this Institution in 1870; and was also a Member of the Institution of Civil Engineers.

Edward Hermann Neville was born in Hamburg on 31st December 1862. After being educated in England, he studied for some years at the Engineering College at Evreux in France, and at Rheydt in Germany. In 1885 he went to Spain, and resided in Madrid, where he devoted himself principally to the electrical and heating department of the firm of Messrs. Julius G. Neville and Co., of Liverpool, of which he was a partner. In 1889 he published in Spanish a treatise on Lathes, which had a considerable success, and

* Proceedings, The Institution of Civil Engineers, 1881-2, vol. lxix. page 337.

during his last illness he wrote, also in Spanish, a treatise on Gas-Engines and their use for industrial purposes. His death took place in Madrid, after an illness of nearly eighteen months, on 9th June 1902, in his fortieth year. He became an Associate of this Institution in 1887.

John Newbigging was born in Glasgow on 26th August 1861. He received his scholastic education in George Watson's College, Edinburgh, and his technical education at Anderson's College, Glasgow. He served his apprenticeship from 1878 to 1883 with the London and Glasgow Engineering and Iron Shipbuilding Co., Glasgow and Govan, in the fitting shop and drawing-office. On its completion, he remained with the firm for a year as a draughtsman. He was then appointed engineer on one of the steamers of the Union Co. of Japan, and with this company he remained until 1886, when he passed the qualifying examination for the Board of Trade certificate. In 1887 he became engineer on one of the Hall Line steamers of Liverpool. From 1888 to 1890 he was draughtsman with Messrs. David Rollo and Sons, engineers, of Liverpool, preparing working drawings, and having charge of the erection of engines and boilers on several large steamers. In 1891 he was appointed an assistant engineer in the office of Mr. Spencer Harty, City Surveyor and Waterworks Engineer of Dublin, being two years in the Waterworks Department. From this he was transferred to the Main Drainage Department in 1892, where he assisted in the preparation of the contract drawings for the new drainage scheme for Dublin, and on the commencement of the outdoor works he was in charge of the construction of several tunnels with complicated curves. After an illness of several months' duration, his death took place at Roundwood, County Wicklow, on 19th October 1902, at the age of forty-one. He became an Associate Member of this Institution in 1902.

Julius Fr. Pajeken was born in Bremen on 16th September 1843. He was educated in Bremen until he was sixteen, when he went to America, and served his time as an apprentice in the Morgan

Iron Works, College Point, Long Island. In 1862 he returned to Germany, and studied for four years in the Technical High School at Hanover. He then worked as a draughtsman in the works of Messrs. Beyer, Peacock and Co., of Manchester, for nearly a year, and in 1867 entered the employment of Messrs. L. Schwartzkopff, locomotive engineers, of Berlin. With this firm he remained thirteen years, and then became foundry engineer at the locomotive works of Hartmann, Chemnitz, Saxony, and for a short time in 1885 in the service of a large paper manufacturer in Berlin. In 1888 he was appointed chief engineer of the firm of Messrs. Ludwig Loewe and Co., Berlin. There his knowledge and skill of works management culminated, in conjunction with Mr. H. F. L. Orcutt, in the design and organization of the factory, which had taken five years in construction. In 1896 he became one of the managing directors of the company, a position he held to the time of his death, which took place in Berlin on 16th December 1902, at the age of fifty-nine. He became a Member of this Institution in 1900.

Henry Albert Parker was born in Chesterfield on 21st November 1848. Having been educated at private schools in his native town, he was apprenticed in 1863 to Messrs. W. Oliver and Co., Engineers, of Chesterfield. On the completion of his term in 1869, he worked as fitter and erector at the Collinge Engineering Works, London, for four years. During that period he superintended the erection of deep-well pumps, the repairing of engines at Chatham Waterworks, and at other undertakings. In 1874 he went to Messrs. Simpson and Co., of Pimlico, as superintending outside engineer, and remained with them until his death. Whilst with that firm he superintended the deepening of deep wells at the Government Waterworks, Trafalgar Square, London, the Three Counties Asylum at Baldock, Herts., and Windsor Castle Waterworks. His death took place at Kennington, London, on 17th July 1902, in his fifty-fourth year. He became an Associate Member of this Institution in 1900.

Samuel Radcliffe Platt was born at Oldham on 1st July 1845, being the son of Mr. John Platt, M.P., and grandson of Mr. Henry

Platt who had founded, in 1821, along with Mr. Elijah Herbert, the firm now called Platt Brothers and Co. He received his early education at Cheltenham College, afterwards studying under a tutor in Berlin for six years. On his return to England he entered his father's works, spending five years in the various shops. On the conversion of the firm into a company, in 1867, he became a director, and, on the death of his father in 1872, was appointed chairman of the company at the age of twenty-seven. From this time his energy was almost entirely absorbed in the works, and as time went on, his enthusiasm and love for the business increased more and more. He acquired a minute as well as a wide general knowledge of the business of machine making, and also of the textile business in which the firm's productions were used. His knowledge of general engineering was wide and practical, and his experience in coal mining added much to his general usefulness. He had a wide commercial knowledge, not only of this country but of foreign commerce, and his annual Address to the Oldham Chamber of Commerce, of which he was President from its inception to his death, showed how great was his interest in political and commercial economics. He was a staunch Free-trader. Everything for the benefit of Lancashire found in him a sympathetic and strong supporter, and, altogether, in his native county, he held a unique position. He had travelled considerably. At the age of twenty he spent seven months in India, and in the following year he visited America. In 1867 he took charge of the exhibit of his firm at the Paris Exhibition ; in 1869 he spent several months in Russia, partly on business and partly for pleasure, and visited America in 1870 and again in 1876, crossing the Atlantic in his own steam-yacht. The record of his life is almost a description of the firm, which has works extending to over 60 acres, and giving employment to nearly 12,000 workpeople. On the occasion of this Institution visiting Hartford Iron Works in 1875,* and in 1894,† he gave the Members a most hearty reception. He became a Member of the Institution in

---

* Proceedings 1875, page 308.
† Do. 1894, page 405.

1867, and was elected a Member of Council in 1900, which position he held to the time of his death. During last Session he contributed a Paper on the "Guarding of Textile Machinery," * which, in conjunction with three other Papers on the Guarding of Machinery, gave rise to a considerable discussion. He was one of the prominent supporters of the Manchester Ship Canal project, and was one of the original directors, retaining that position to the last. In 1873 he was made a county magistrate, and a Justice of the Peace in 1886. He was also high sheriff of the county in 1897, and a deputy lieutenant. In 1882 he was elected a town councillor; three years later he became an alderman, and in 1887 he was raised to the mayoralty, an office which he held for two years in succession. His health had been indifferent from the beginning of 1901, and later in that year he found himself compelled to give up work. In July 1902 he went for a cruise in his yacht, the ultimate destination being the Mediterranean, but he did not get farther than the Menai Straits, his condition being too critical for movement; and there, after a painful illness due to an internal abscess, he died on 6th September 1902, at the age of fifty-seven.

Sir William Chandler Roberts-Austen, K.C.B., was born in London on 3rd March 1843. At the age of eighteen he entered the School of Mines, with the idea of becoming a mining engineer; but upon obtaining the associateship of the school, the late Professor Graham, then Master of the Mint, secured his services; and on the death of Professor Graham in 1869 he was appointed assayer, being promoted in 1882 to the position of Queen's Assay-Master. All the scientific, as distinguished from the mechanical, operations of coinage, were ultimately placed in his charge, and, up to the time of his death, he had been responsible for the standard fineness of about one hundred and thirty millions of gold coin. In 1880 he succeeded Dr. Percy as Professor of Metallurgy at the Royal School of Mines, while still occupying his post at the Mint; and from that time dates the beginning of his

---

* Proceedings, 1902, page 221.

long series of experimental research on the atomic theory of metals, and of the influence of traces of impurities on the whole mass. In 1889 the Alloys Research Committee of this Institution was appointed, and he acted as Reporter to it, practically carrying out all the tests. This Committee has made five Reports, and the sixth and final one was in draft form before his death. The First Report * dealt with silver and gold and their impurities; and the cooling-curve system in connection with alloys was evolved, which has been so advantageously developed. In the Second Report † the effects of arsenic, antimony, and bismuth on copper were shown, and the thermal behaviour of chromium steel was treated. The freezing points of metals were discussed in the Third Report, ‡ and data on the effects of alloying aluminium with iron, copper, and nickel were given. The Fourth Report § dealt with brasses, coppers, diffusion of metals, and the relation between the melting points of alloys and the atomic volumes of their constituent metals. In the Fifth Report ** various alloys were discussed, and the treatment of carburised iron and low carbon rail-steel were dealt with. On the completion of the Sixth and final Report, which Sir William, unfortunately, did not live to present to the Institution, the work of this Committee will be proceeded with at the National Physical Laboratory. For the purpose of recording temperatures automatically he brought into use by means of photography his automatic recording pyrometer. A description of this instrument was given in Papers read before the Iron and Steel Institute in 1891, 1892, and 1893, as well as before this Institution.†† Alloys formed the topic of his lecture to the British Association at their Newcastle Meeting in 1889, dealing with the hardening and tempering of steel, which was the means of beginning that long association with M. Osmond, the French metallurgist.

---

* Proceedings, 1891, page 543.
† Do. 1893, page 102.
‡ Do. 1895, page 238.
§ Do. 1897, page 31.
** Do. 1899, page 35.
†† Do. 1891, page 546.

On several Government Committees he rendered service. In 1893 he was chairman of a committee appointed to enquire into the laboratory arrangements of the Customs and Inland Revenue Departments; and in the same year he served on a committee appointed to consider the best means of utilising for metallurgical purposes the water-power available on the completion of the Periyar Water Works in India. In 1896 he served on a Board of Trade Committee on the cause of the deterioration of steel rails, in connection with which he conducted an elaborate research, and furnished a report of great industrial importance. He was also a member of the Explosives Committee of the War Office from the time of its formation. He was elected an Honorary Member of this Institution in 1897, in recognition of his valuable work on the Alloys Research Committee, and was President of the Iron and Steel Institute in 1899–1900; he was also elected an Honorary Member of the Institution of Civil Engineers in 1901. He was one of the founders of the Physical Society of London, of which he was for some time secretary, and afterwards a vice-president; and acted as an honorary secretary of the British Association for the Advancement of Science. In 1875 he became a Fellow of the Royal Society, and served on the Council. He was also a vice-president of the Chemical Society and of the Society of Arts. In 1890 he was created a Companion of the Bath, and was promoted to be a Knight Commander in 1899; the University of Durham conferred the title of D.C.L. in 1897, and he was a Doctor of Science of Victoria University, Manchester. He had served on the Government Commission in connection with the Exhibitions of Paris in 1889, and in Chicago. He was a Knight of the Legion of Honour, and in 1893 he was elected a member of the Athenæum Club for distinguished eminence in science. His death took place at the Royal Mint, London, on 22nd November 1902, at the age of fifty-nine.

John Robinson was born at Skipton on 27th March 1823. He was educated at Skipton Grammar School, a school in Manchester, and the Wakefield Proprietary School. In 1839 he was apprenticed

to Messrs. Sharp, Roberts and Co., and in 1843 became a partner in the firm. The business was converted in 1863 into a limited company, and he became vice-chairman and co-managing director with the chairman, the late Mr. C. P. Stewart, on whose death in 1882 he became chairman of the company, and remained in that position till one year after the removal of the company to Glasgow, in 1889, when he retired. He was called upon by Mr. Cobden to take part in the discussion of the French Treaty of Commerce in 1851, and was a Member of the Jury at the Paris Exhibition in 1878, when he was elected an Honorary Member of the Société des Ingénieurs Civils of France. He joined the Institution of Mechanical Engineers in 1859, and was elected a Member of Council in 1866. On two occasions he was elected a Vice-President, and became President in 1878, being re-elected in 1879. He contributed to this Institution a Paper on Giffard's Injector for feeding steam boilers,* which was followed by a Supplementary Paper in the same year; and in 1866 he read a Paper on Seller's Self-adjusting Injector.† He also read a Paper on the distribution of weight on the axles of locomotives.‡ He was a Member of the Institution of Civil Engineers, and of the Iron and Steel Institute, and was for many years a member of the Governing Body of the Owens College, Manchester, and afterwards of the Victoria University in that city. His death took place at his residence, Westwood Hall, Leek, Staffordshire, on the 9th July 1902, at the age of seventy-nine.

John Shepherd was born on 29th April 1816 at Burley-in-Wharfedale, and served his time in the works of Messrs. Foster and Fison, of the same town. At the age of twenty-one he left his native place and went to Leeds, where he worked for a short time at Messrs. Fairbairn's, and afterwards at Messrs. Ardill and Pickard's works. In 1844 he commenced business on his own

* Proceedings 1860, pages 39 and 74.
† Do. 1866, page 266.
‡ Do. 1864, page 92.

account, and for fifty years was the senior partner in the firm of Shepherd, Hill and Co., machine tool makers, who were contractors to the War Department, the Admiralty, the various Colonial and Foreign Governments, &c., and obtained prize medals at the London Exhibitions of 1851 and 1862, and the Paris Exhibitions of 1855 and 1867. His death took place in Leeds on 18th November 1902, in his eighty-seventh year. He became a Member of this Institution in 1861.

Andrew Stewart was born at Johnstone, near Glasgow, on 9th September 1832. In 1860 he founded the first of the many important enterprises connected with his name. It was known as the Clyde Tube Works, Glasgow, and occupied a portion of the site on which now stands the hotel and station of the Glasgow and South Western Railway. In 1867 he commenced to lay down new works at Coatbridge, in close proximity to the coal and iron fields of Lanarkshire. In this undertaking he was joined by his brother James. In 1882 the firm was converted into a company, under the title of Andrew and James Stewart, Limited, the shareholders being composed entirely of those actively employed in the business. The progress and expansion of the business became so rapid, that the company acquired the Sun Tube Works, Coatbridge, and the Clyde Pipe Foundry. Seven years later the British Tube Works were built by two of his sons, and in 1890 these works and the Clydesdale Iron and Steel Works of Mossend were amalgamated with those of the firm under the title of A. and J. Stewart and Clydesdale. Following immediately on this amalgamation, the steel smelting and heating furnaces at Clydesdale were entirely rebuilt, and three new rolling mills were put down. In 1898 the company was amalgamated with that of Messrs. James Menzies and Co., of Phœnix Tube Works, Rutherglen, under the title of A. and J. Stewart and Menzies. He was a liberal contributor to the schemes for the better development of the University of Glasgow, and founded there the Adam Smith Chair of Political Economy. These actions were recognised by the University conferring upon him the degree of LL.D. The Town

Council of Coatbridge recently desired to present him with the freedom of the burgh, but the state of his health prevented its acceptance. His death took place at his country residence at Peebles, after a long illness, on 16th August 1901, in his sixty-ninth year. He became a Member of this Institution in 1887.

WILLIAM THORBURN was born in Durham on 4th October 1860. Having been educated at the Liverpool Institute High School, he served his apprenticeship at the Ditton Brook Iron Works from 1877 to 1881, and was then appointed assistant engineer to the Decido Iron Ore Co., Spain. There his work consisted in the opening up of mines and the construction of a chain railway. After three years spent in England on private business, he returned to Spain in 1887, and two years later was appointed resident engineer to the San Salvador Iron Ore Co., superintending the erection of ore-washing plant and the construction of a chain railway. On the completion of the works in 1891, he was engaged by Mr. Joseph MacLennan as resident engineer on his works near Santander, which consisted of a mining railway, large iron-ore working plant, &c. He remained in this position until the works were transferred to a company in 1896, when he was appointed engineer to the Luchana Mining Co., at Bilbao; in 1900 he became general manager. This position he held up to the time of his death, which took place at Liscard, Cheshire, on 22nd August 1902, in his forty-second year. He became a Member of this Institution in 1899.

JAMES MICHAEL GRAHAM WILSON was born in Cape Town on 29th April 1862, and was educated in Cape Colony. He served four years' apprenticeship in the Castle Line at sea, after which he was engaged for eight years in the timber trade with Messrs. Wilson and Glynn, and with the Cape Government Railways, where he was general assistant to the works inspector. He was also employed for one year as overseer for the Wemmer Gold Mining Co., at Johannesburg. In 1892 he came to England, and entered the Polytechnic School of Engineering as a student, where he remained until 1895. He was then employed as a draughtsman to the commissioners of Bray,

Co. Wicklow, for a few months, when he became an assistant mains engineer of the London Electric Supply Corporation. In 1899 he returned to Cape Town, and was employed in the office of the Director of Railways. His death took place at Cape Town, on 12th November 1901, in his fortieth year. He became an Associate of this Institution in 1899.

INDEX.

1902.
Parts 3–5.

LIQUID FUEL FOR STEAMSHIPS.

Burners.

Fig. 1. *Körting.*

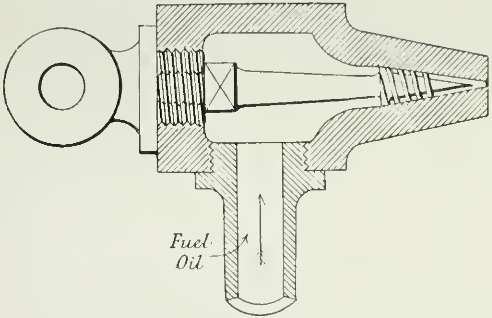


Fig. 2. *Swensson.*

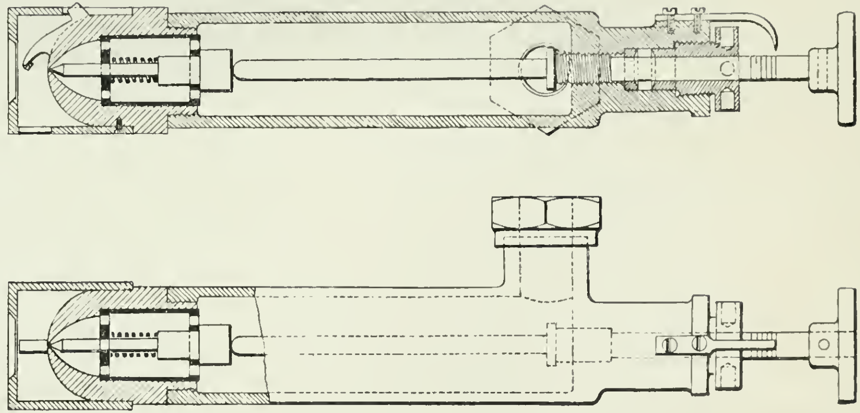
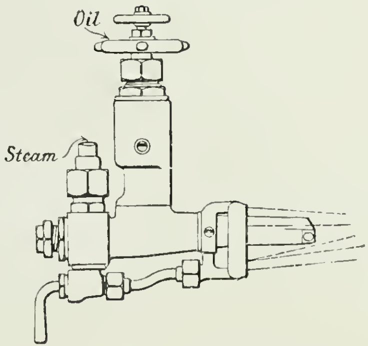
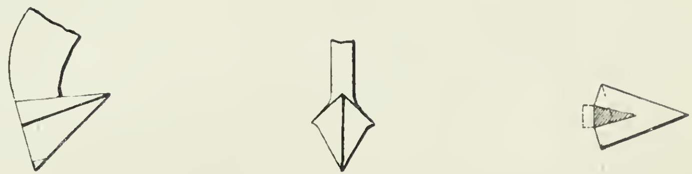


Fig. 3. *Holden.*





Enlarged Views of Tongue Sprayer.

Plate 12.

Burners.

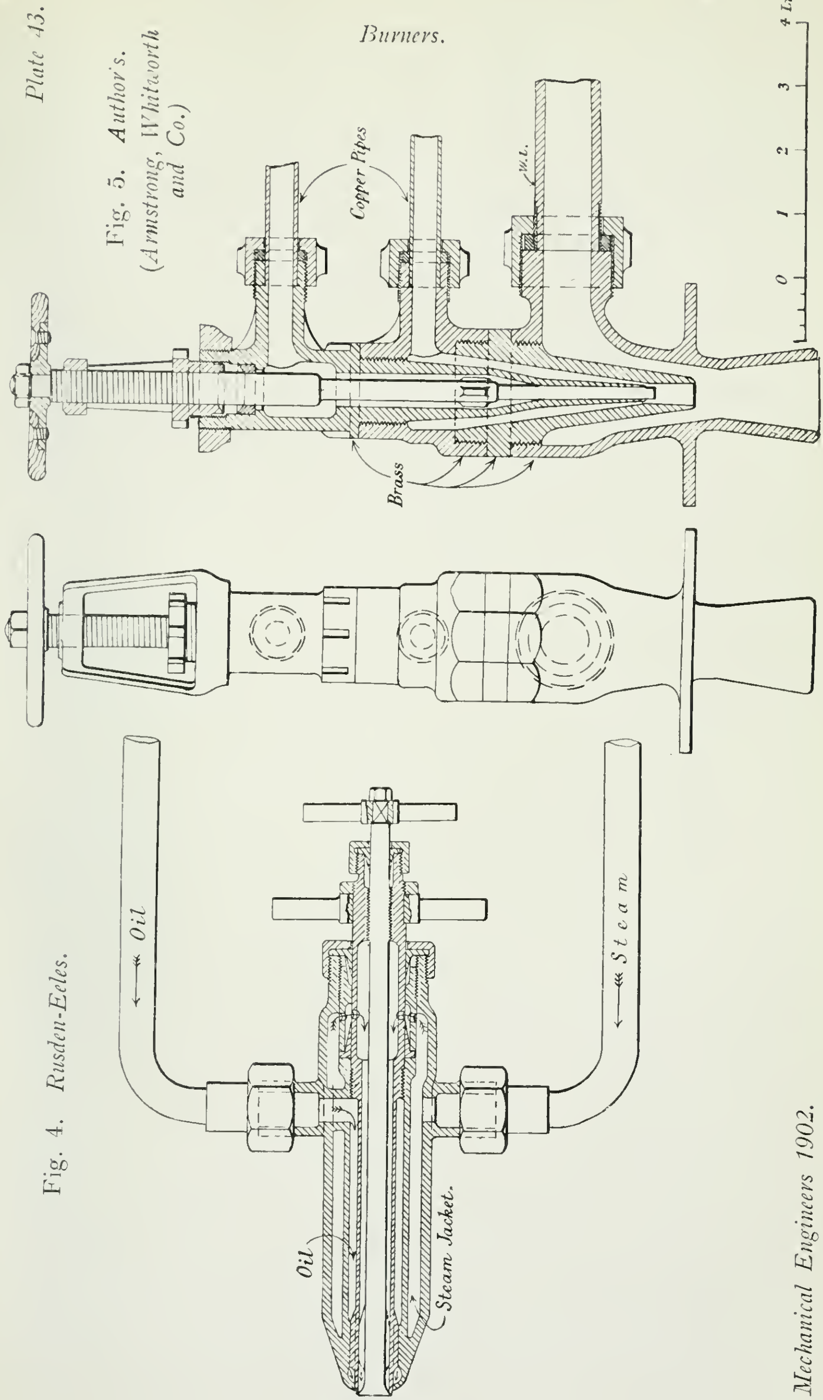


Fig. 5. Author's. (Armstrong, Whitworth and Co.)

Fig. 4. *Rusden-Eeles.*

Plate 43.

Fig. 6. *Arrangement of Combined Oil and Coal Fuel Installation with Forced Draught (Howden).*

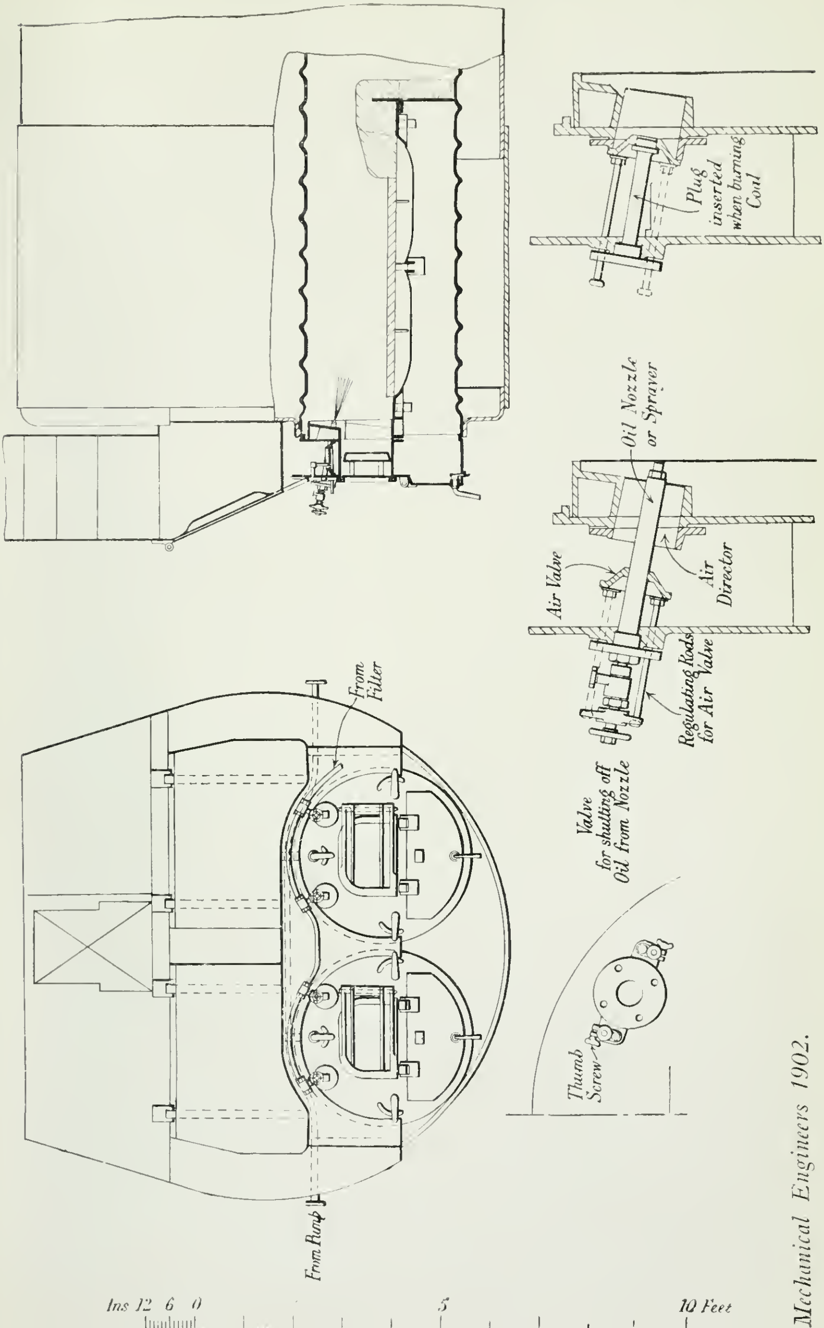
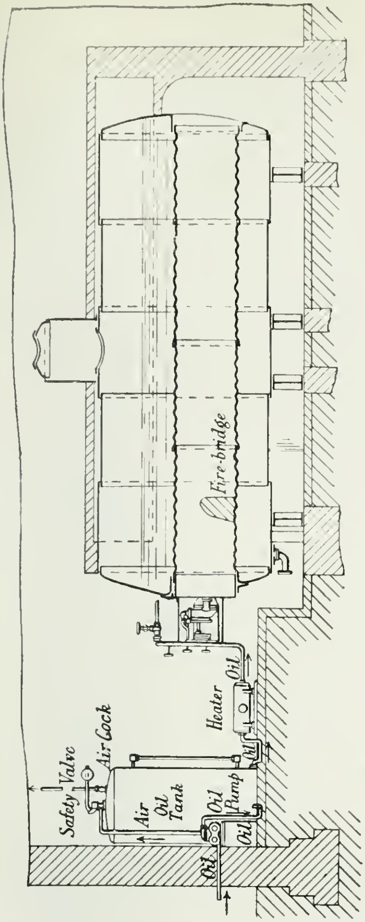
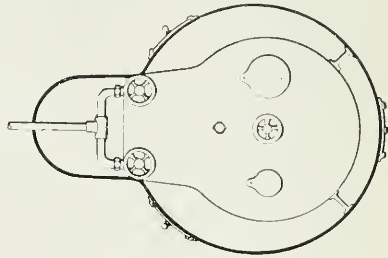
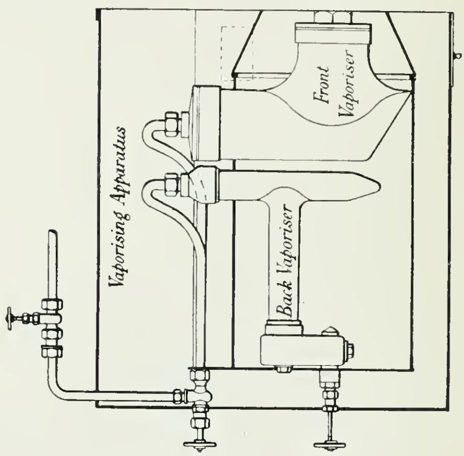


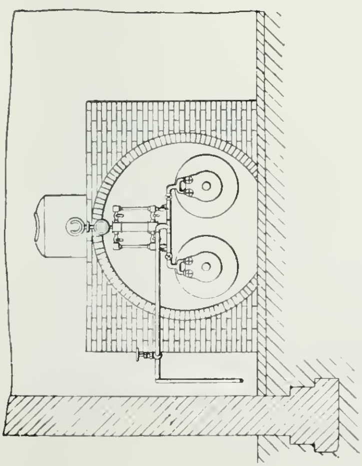
Fig. 7.

Vapour Burner (Dürr).









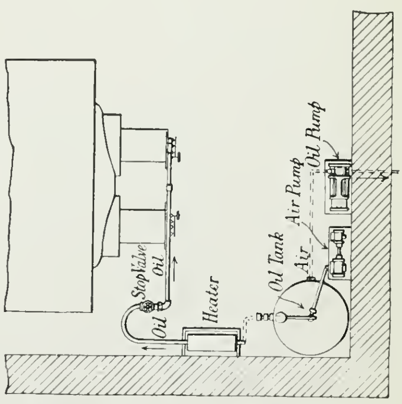


Fig. 8. *Water Separator.*

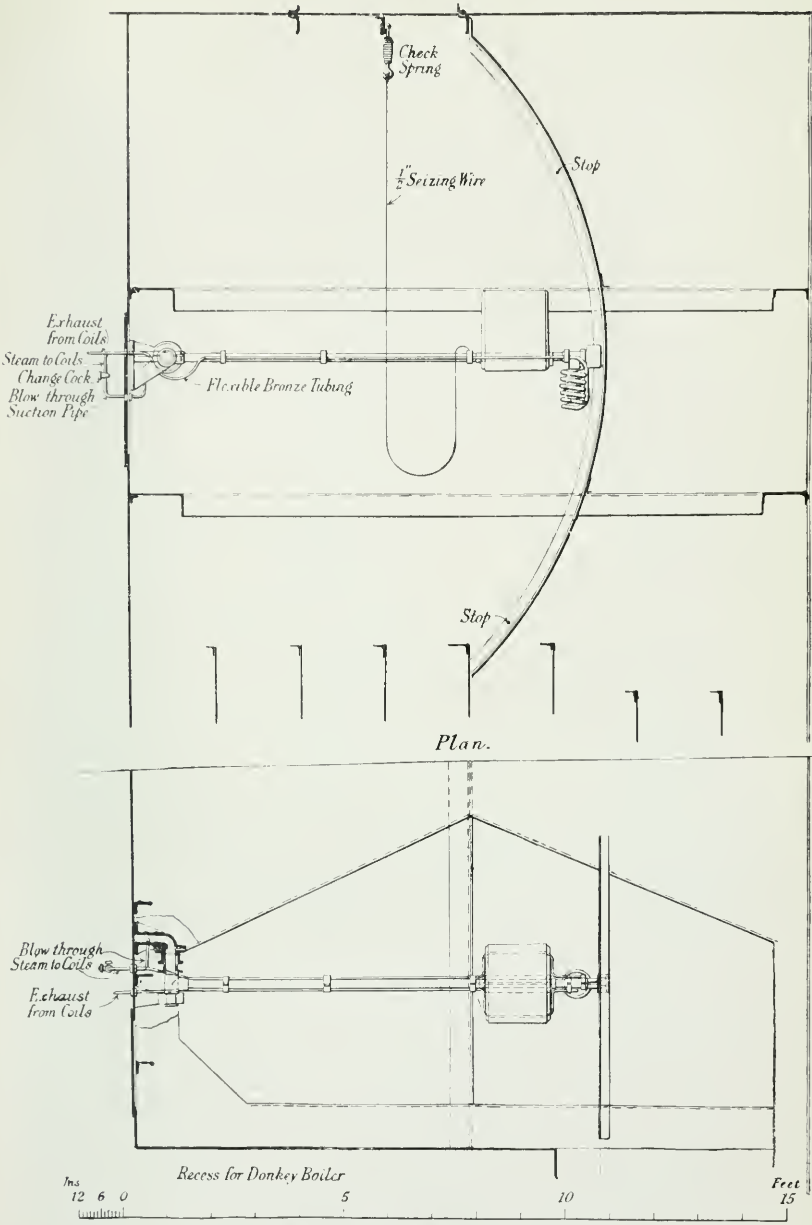


Fig. 1. *General Plan of Pumping Plant for Circulating Water through Condensers.*

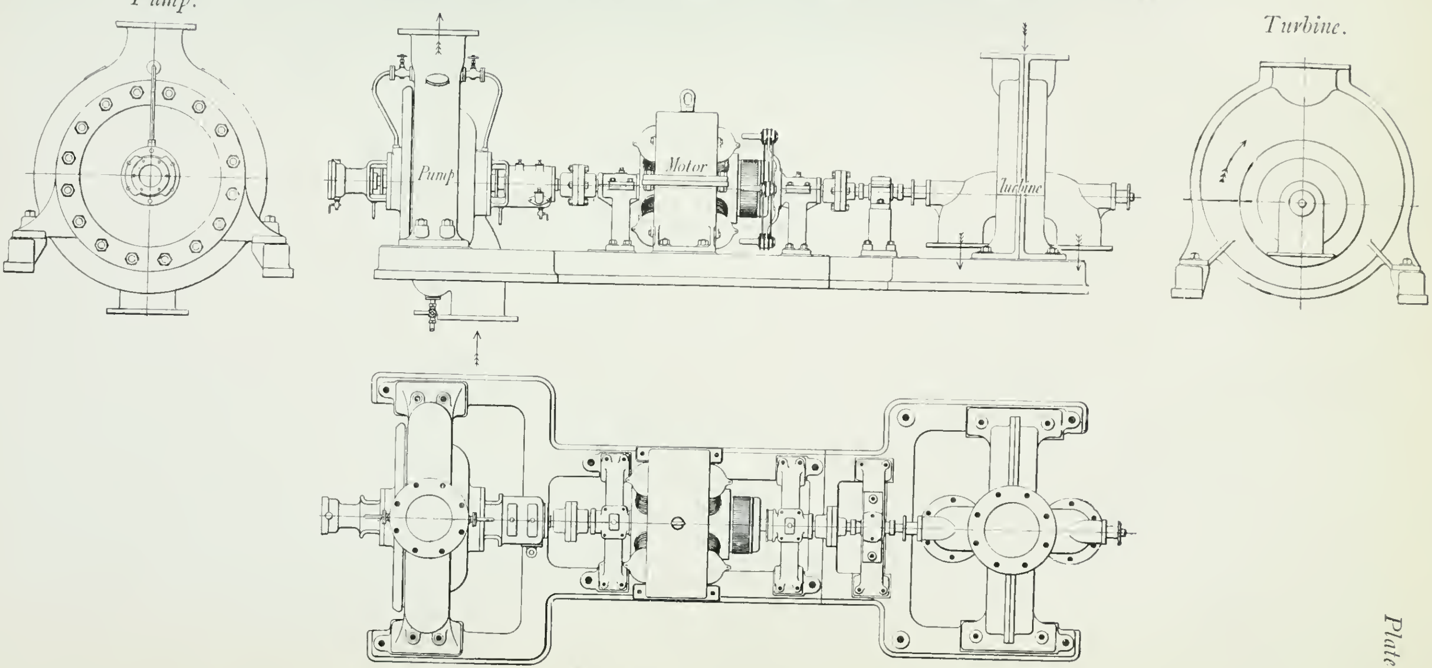
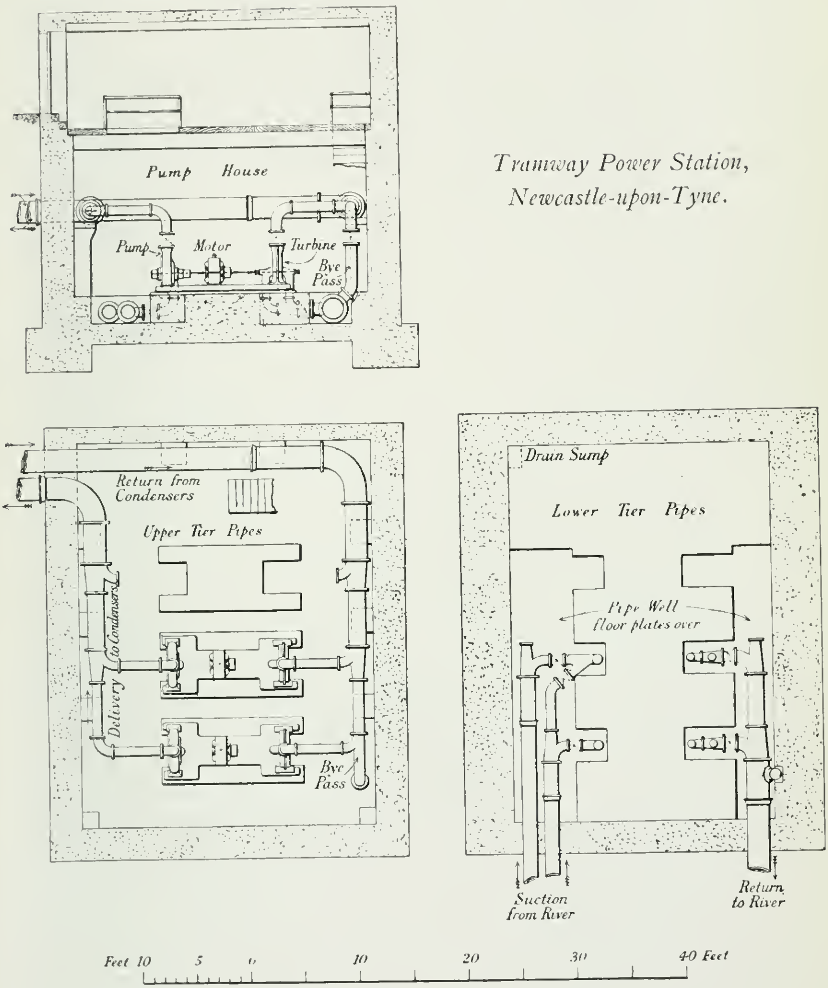


Plate 47.

Fig. 2.

Circulating Pumps.

Tramway Power Station, Newcastle-upon-Tyne.



Circulating Water Installation.

High Lift Centrifugal Pump (Single Chamber) Bucket $23\frac{5}{8}''$ (600·6 $^{m}/_{m}$) *diam.*

Fig. 3. *Constant Delivery of* 1,250 *Gallons per minute (approx.).*

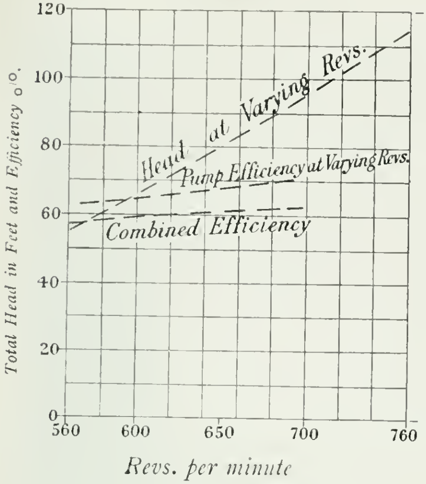
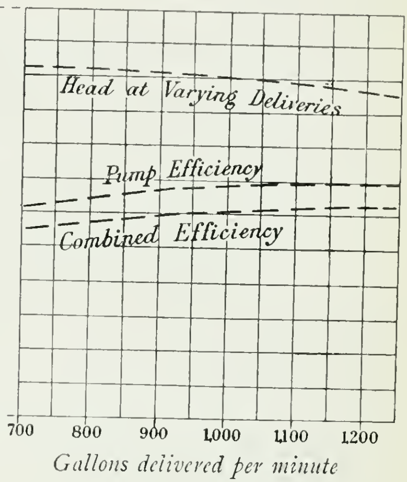


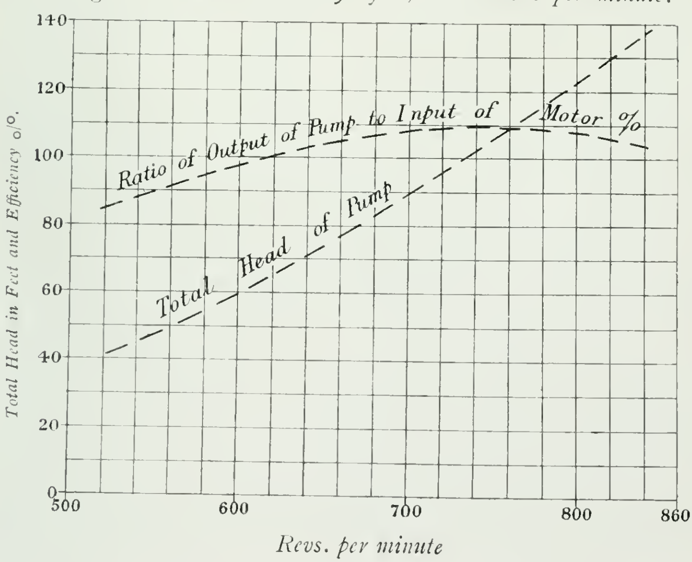
Fig. 4. *Constant Speed of* 700 *Revs. per minute (approx.).*



NOTE.—*Head includes a constant suction of about* 15·5 *feet.*

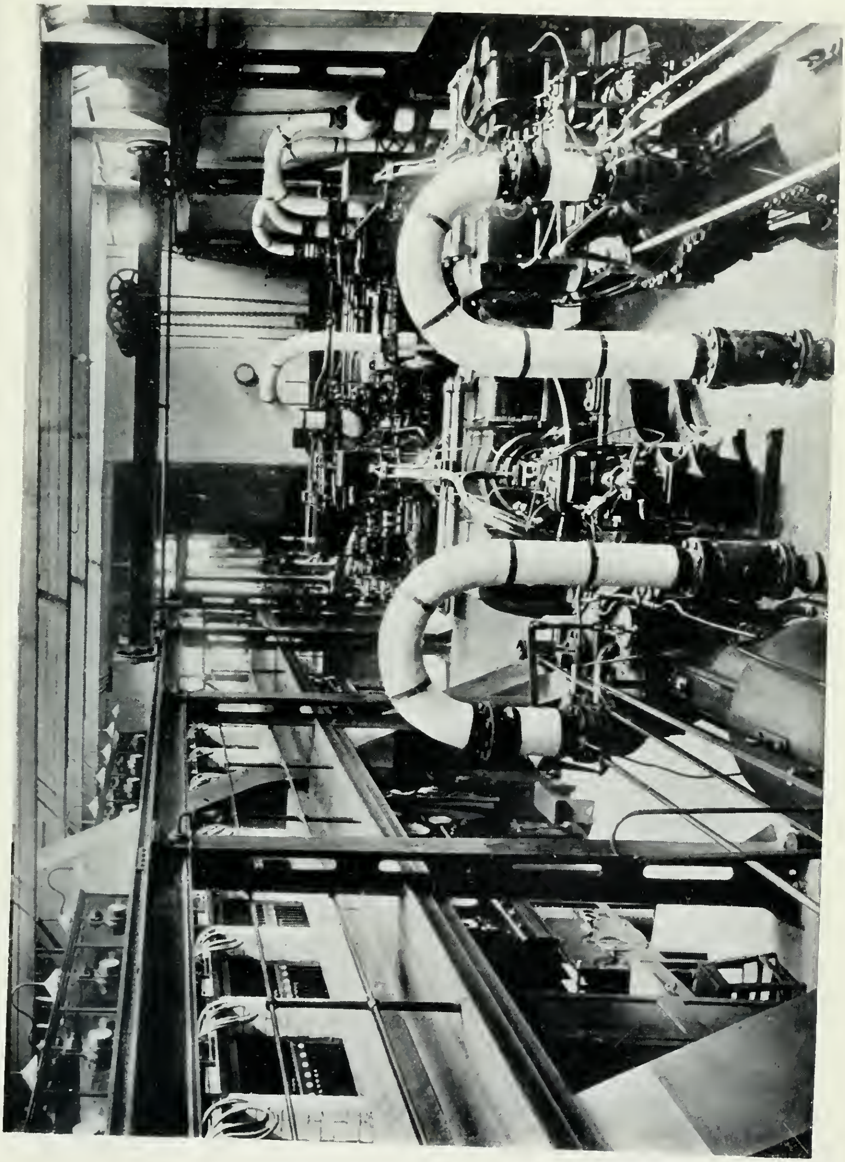
Combined Pumping Plant Test.

Fig. 5. *Constant Delivery of* 1,250 *Gallons per minute.*



NOTE.—*Average Head on Turbine is about* 1 *ft. less than Delivery Head on Pump, or about* 9·3 *ft. less than Head shown on Curve. Average Constant Suction on Pump*=8·3 *feet.*

Fig. 1. *Engine Room from North End, Forth Banks Works.*



Forth Banks Works.

Fig. 3.
Jet-Condenser.

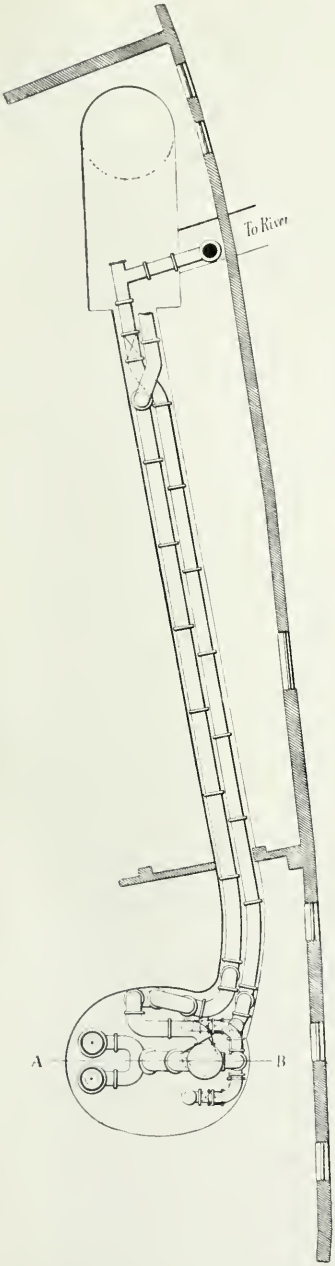


Fig. 2.
Surface Condensing Plant.

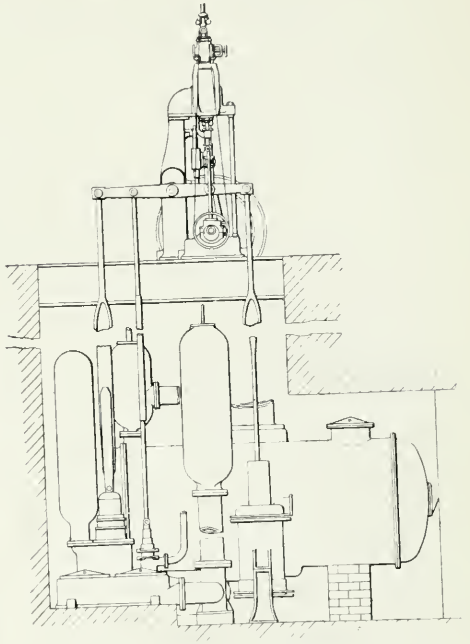


Fig. 4. *Section on line* A.B. *Fig. 3.*

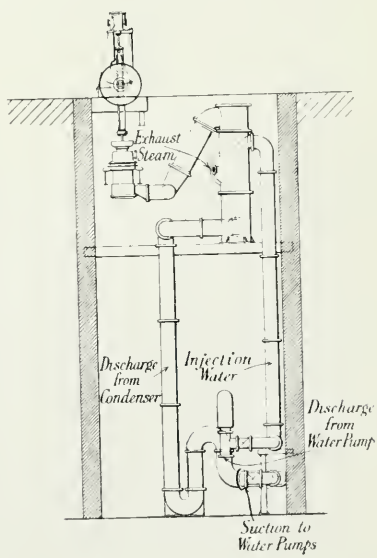


Fig. 5. *Cross Section, Close Works.*

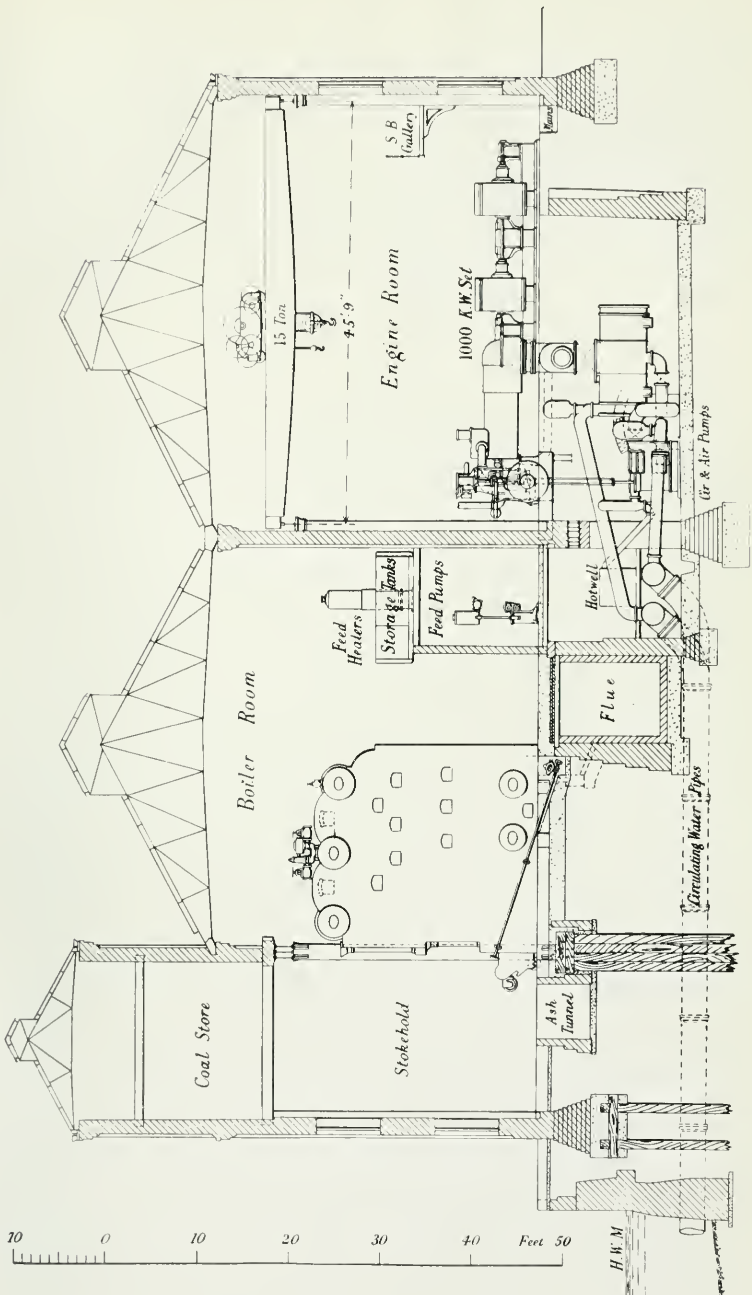


Fig. 6. *Boiler Feed Pump.* $\left.\begin{array}{l}\textit{Steam Cyl. } 12\frac{1}{2}'' \\ \textit{Water } ,, \quad 9\frac{1}{2}''\end{array}\right\}$ *24" Stroke.*

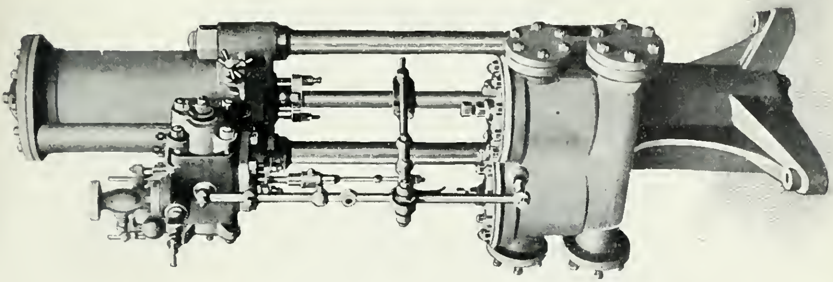
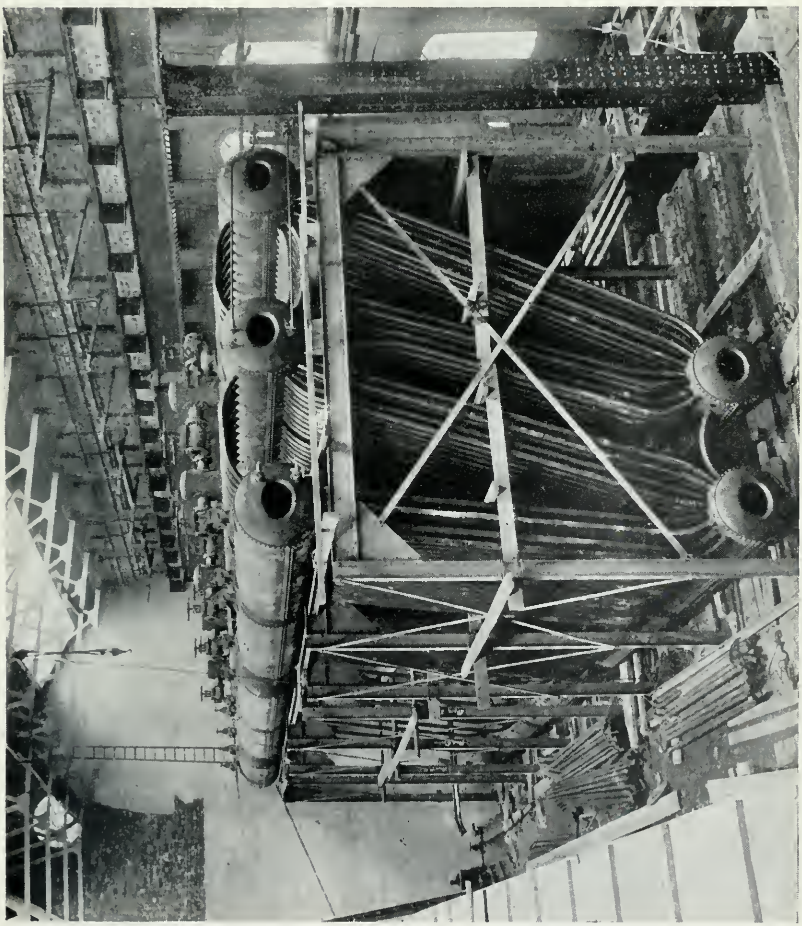


Fig. 7. *Back View of Boilers, Casing incomplete, Close Works.*



FORTH BANKS AND CLOSE POWER STATIONS.

Fig. 8. *1,000 Kw. Generator for Close Works.*

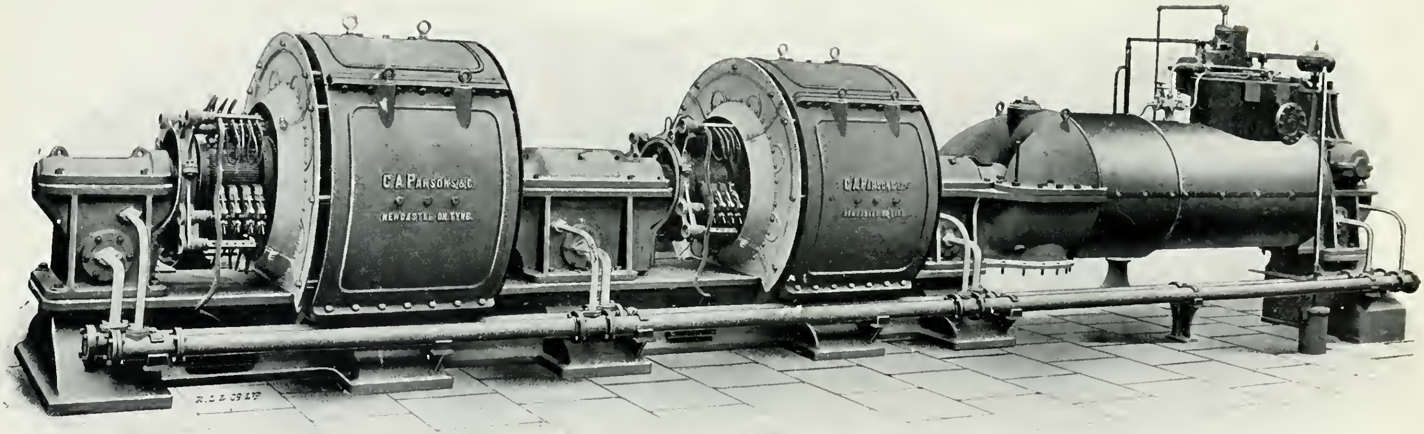
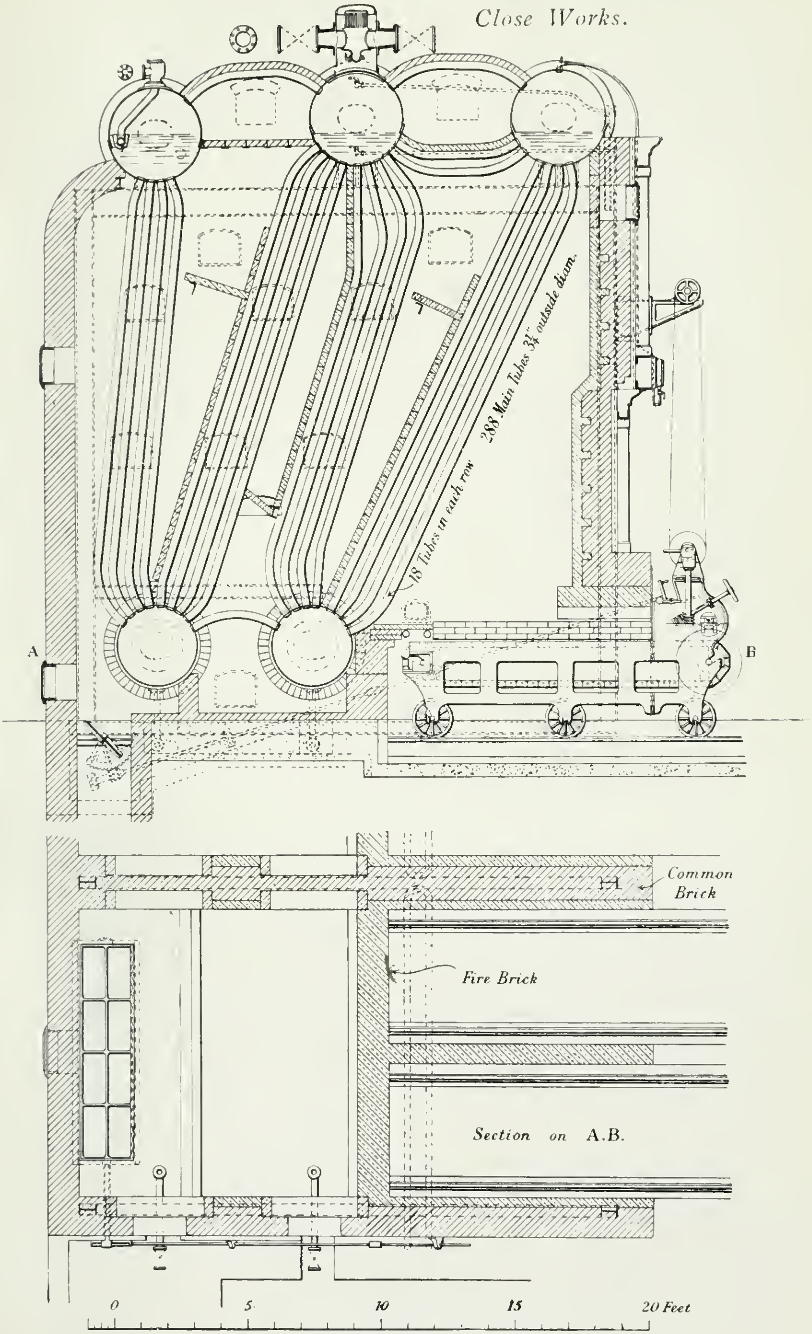


Fig. 9. *Stirling Boilers. Cross Section of 1 of the 5.*

Close Works.



Four Schemes for Discharging Coal, Close Works.

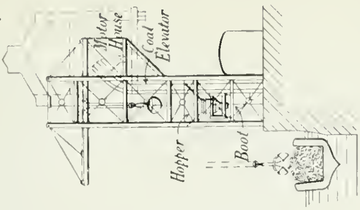


Fig. 12. Scheme (C).

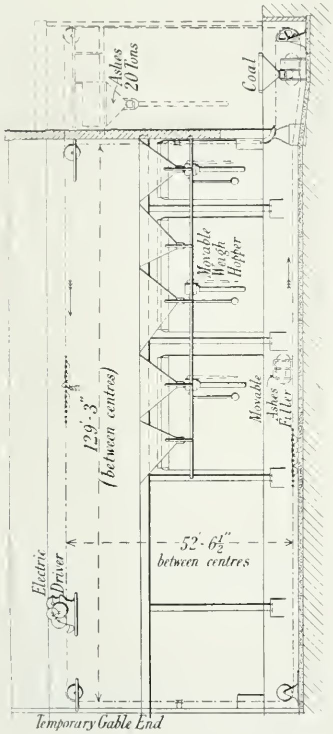


Fig. 11. Scheme (B).

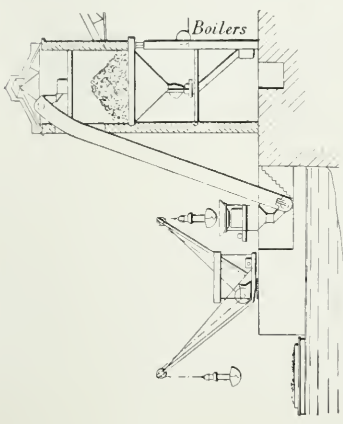


Fig. 10. Scheme (A).

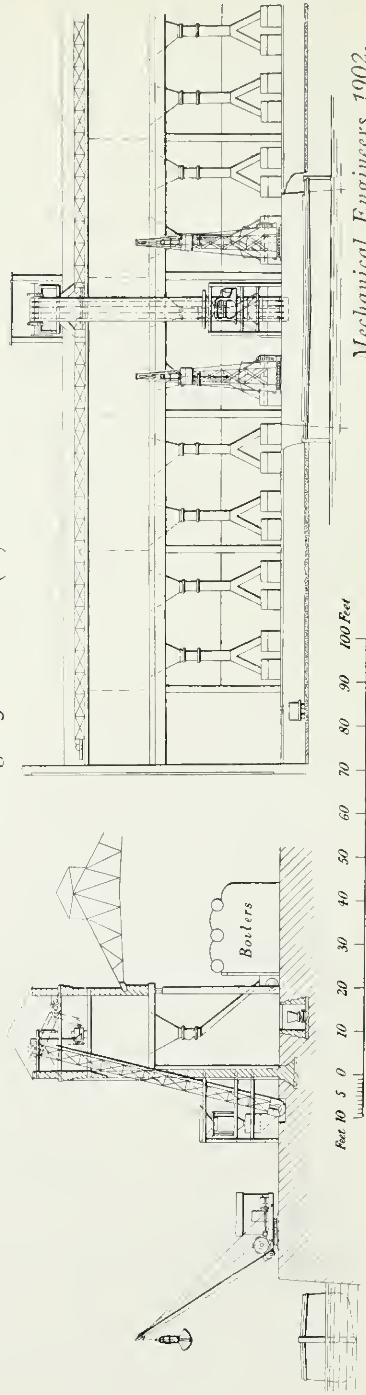


Fig. 13. Scheme (D).

Fig. 14. *Three-Wire Switchboard, Close Works.*

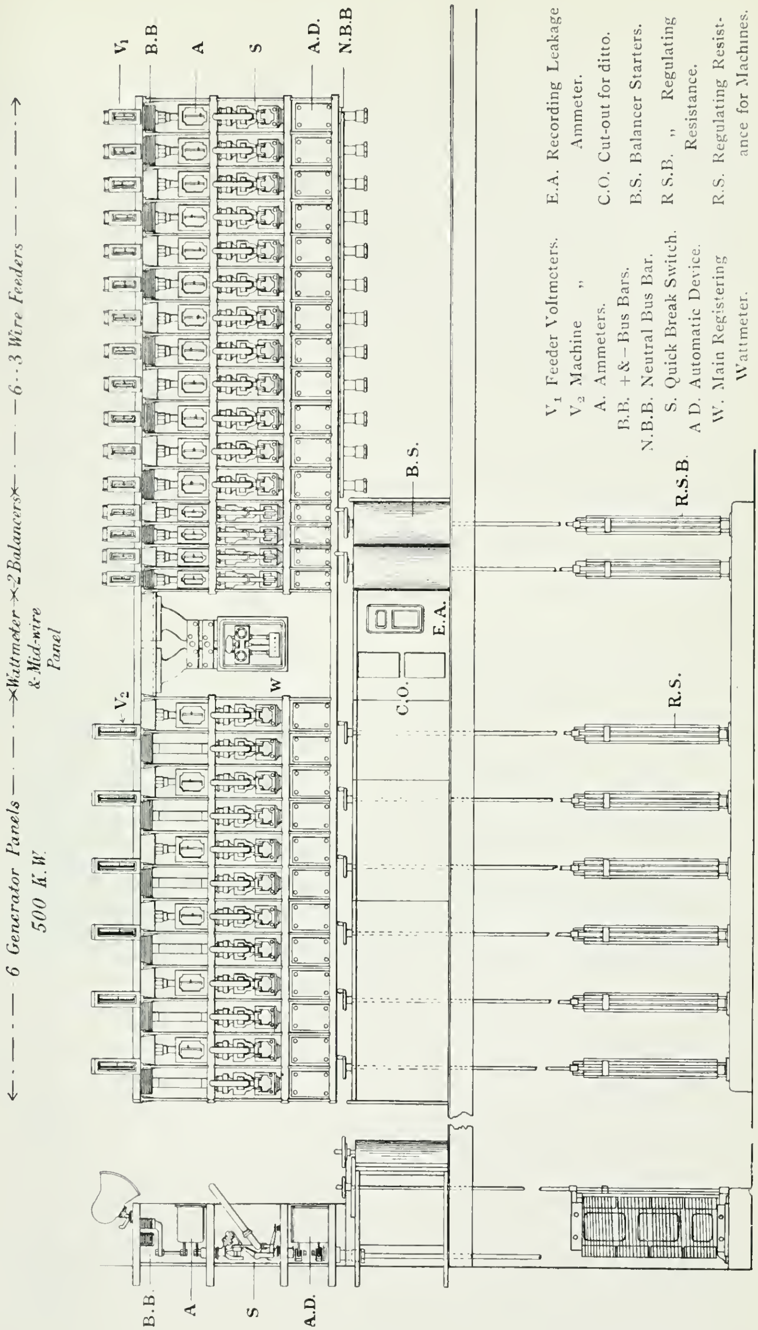


Fig. 4. *Triple-Expansion Engine.*
Cyls. 17½", 28½", 48". *Stroke* 36". 190 *lbs. w.p.* *Revs.* 100 *per min.*
coupled to 700 *Kw. Three-Phase Alternator,*
June, 1901.

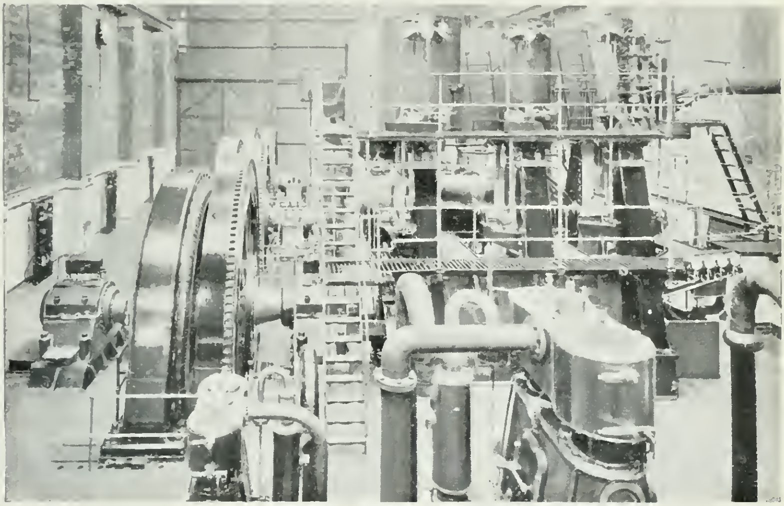


Fig. 5. 1,500 *Kw. Turbo-Alternator (Parsons).*

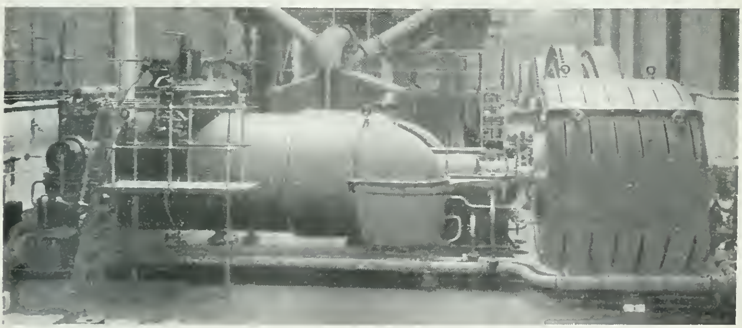
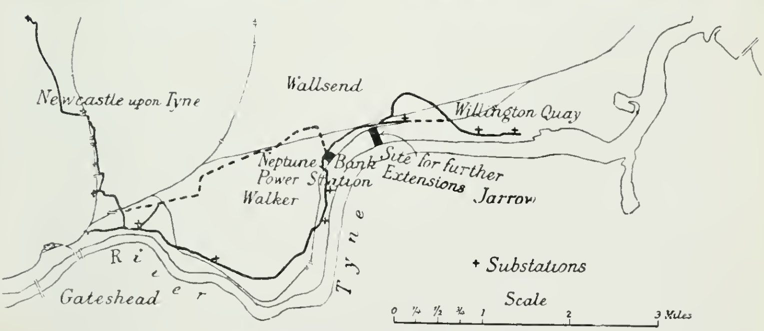


Fig. 6. *Route of Transmission Mains.*



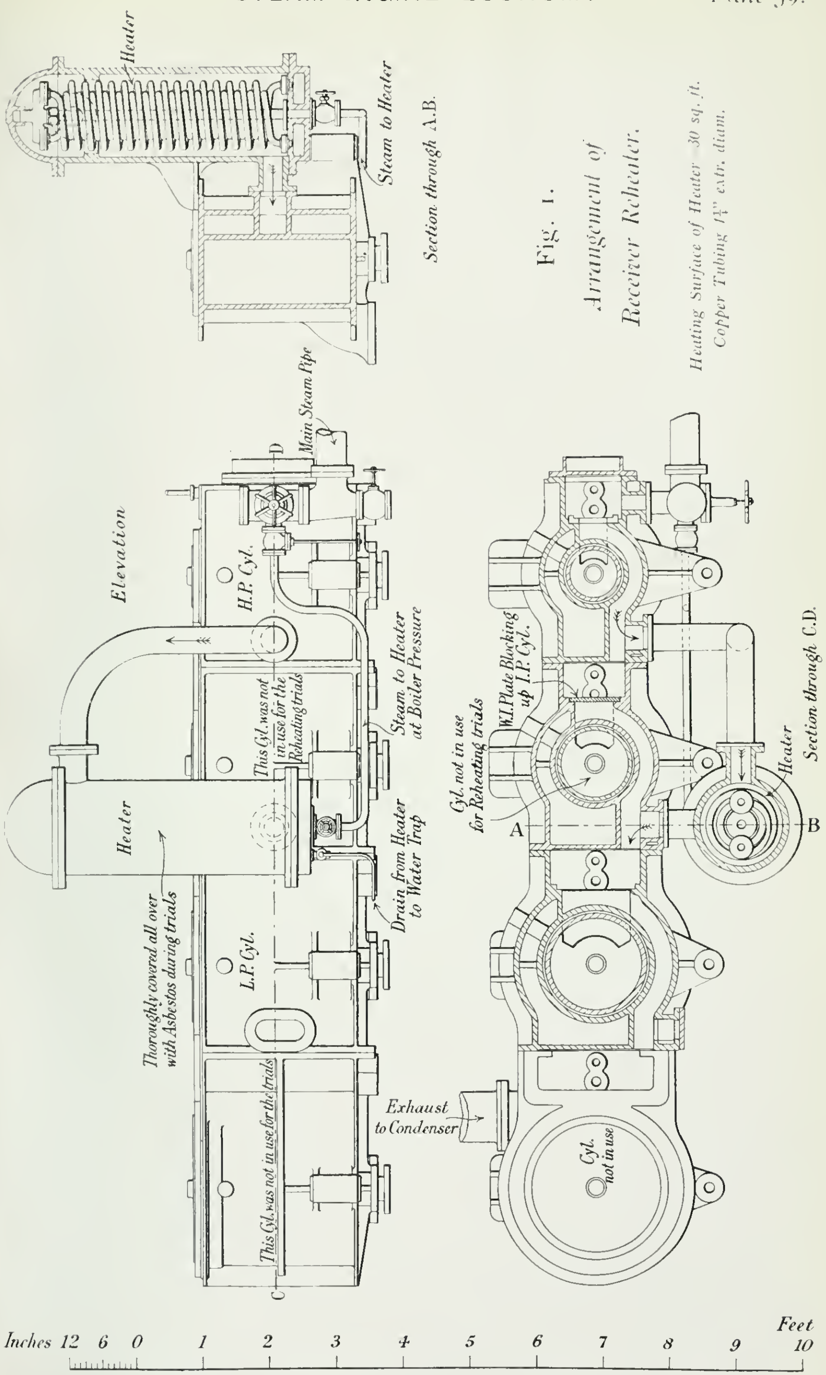


Fig. 1.

Arrangement of Receiver Reheater.

Heating Surface of Heater 30 sq. ft.
Copper Tubing 1¼" extr. diam.

Fig. 2. Results of Receiver Reheating Trials.

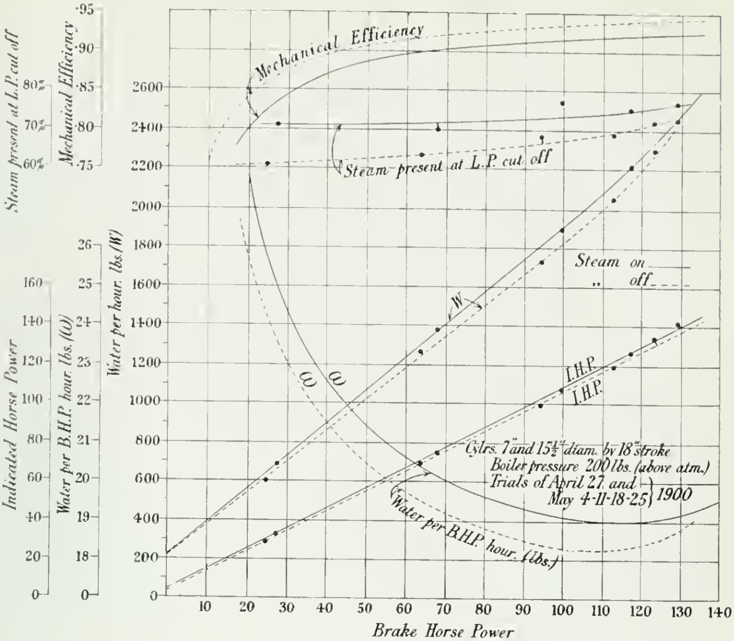


Fig. 3. Results of Vacuum Trials.

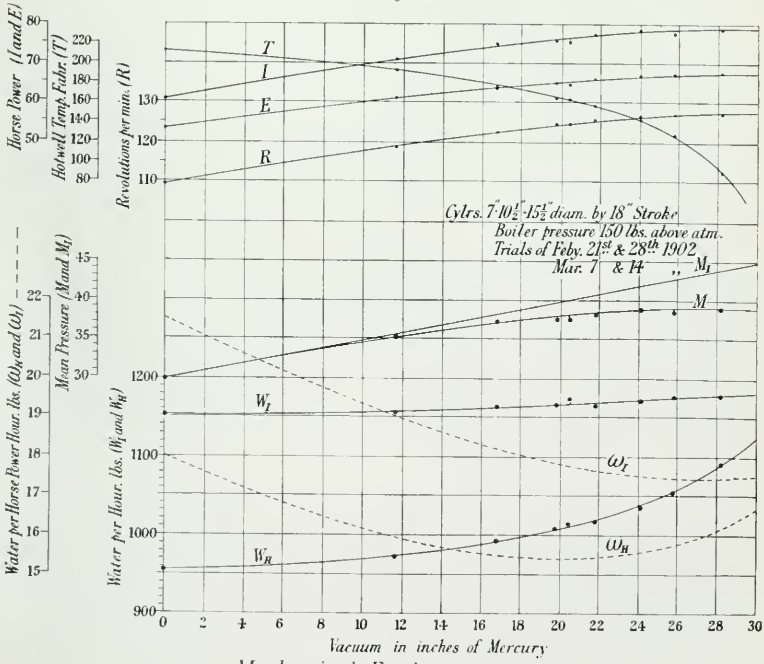


Fig. 1. *Express Engine. Cyls. 19" × 24". Wheel 7'-7⅛".*

Fig. 2. *Three-Cyl. Compound altered from Two-Cyl., 1898. H.P. Valve, Plate 64.*

Fig. 3. *Express Passenger Engine, Cyls. 19" × 26", Wheel 6'–10", 1899. Details, Plates 64—68.*

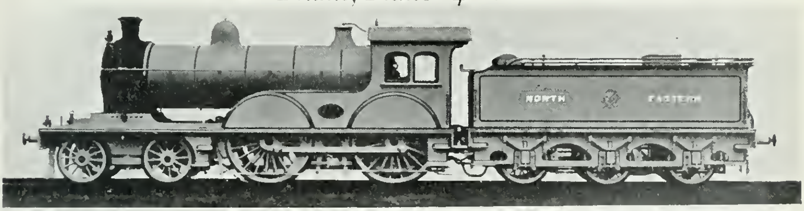


Fig. 4. *Six-Coupled Passenger Engine, Cyls. 20" × 26", Wheel 6'–8", 1901. Valve, Plate 64. Cyls., Fig. 14.*

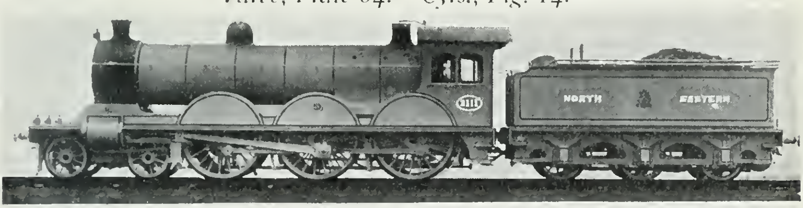
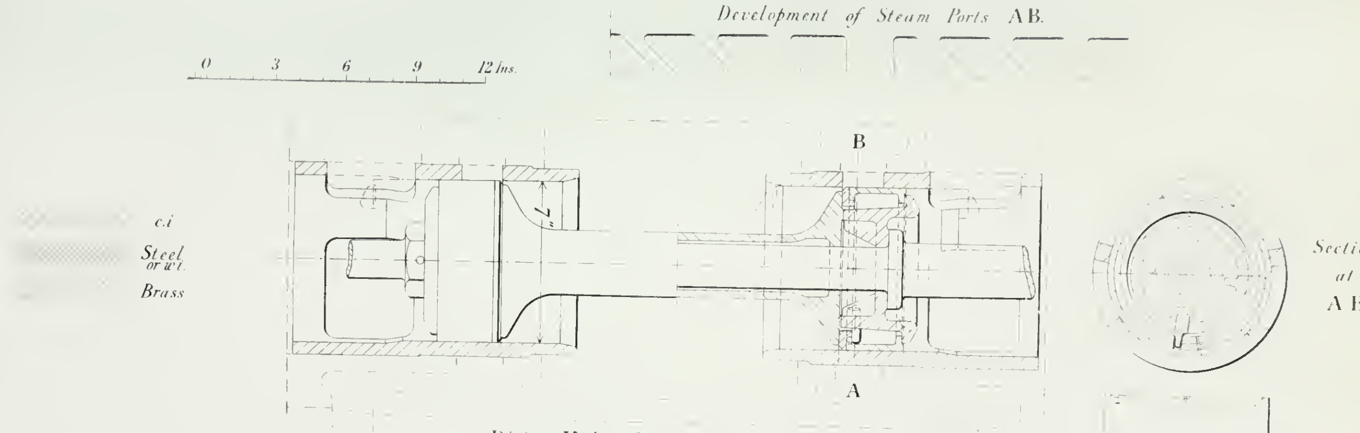


Fig. 5. *Eight-Coupled Mineral Engine, 20" × 26", 1901. Valve, Pl. 64.*

Fig. 6. 7"-Piston Valve fitted to a Compound Passenger Engine, 1888.



Piston Valve fitted to a Goods Engine, 1896.

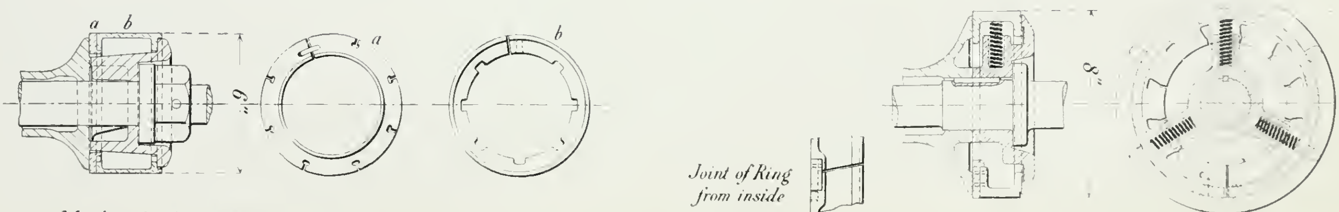


Fig. 7. First Method.

Fig. 8. Improved Method.

Scale 1/8th.

CYLINDRICAL VALVES FOR LOCOMOTIVES.

Fig. 9. *8"-Valve, 1894.*

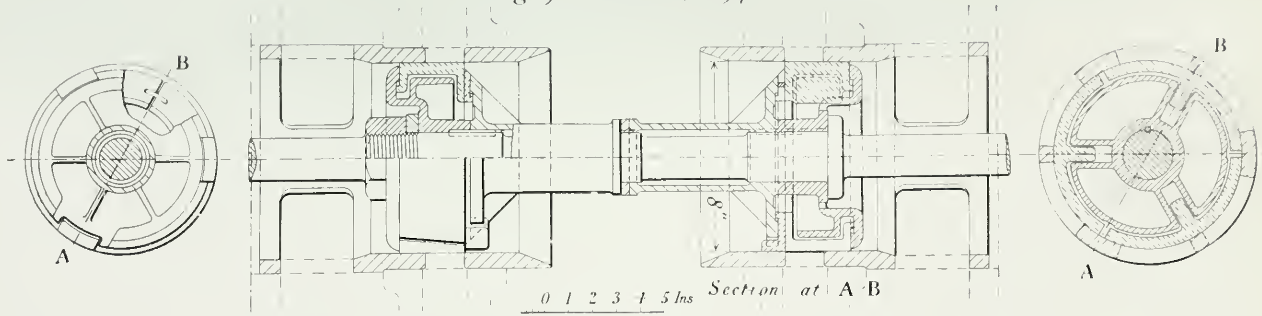
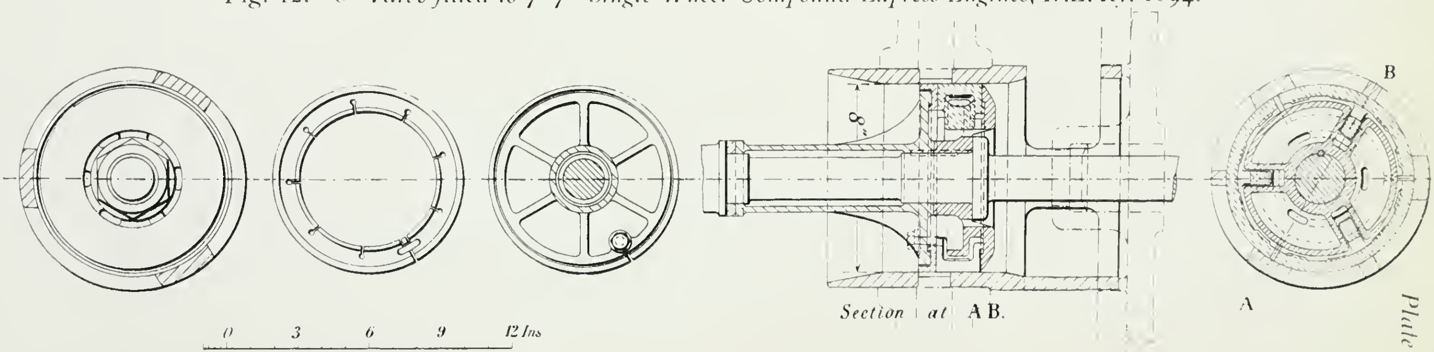


Fig. 12. *8"-Valve fitted to 7'-7" Single-Wheel Compound Express Engines, N.E. Ry. 1894.*



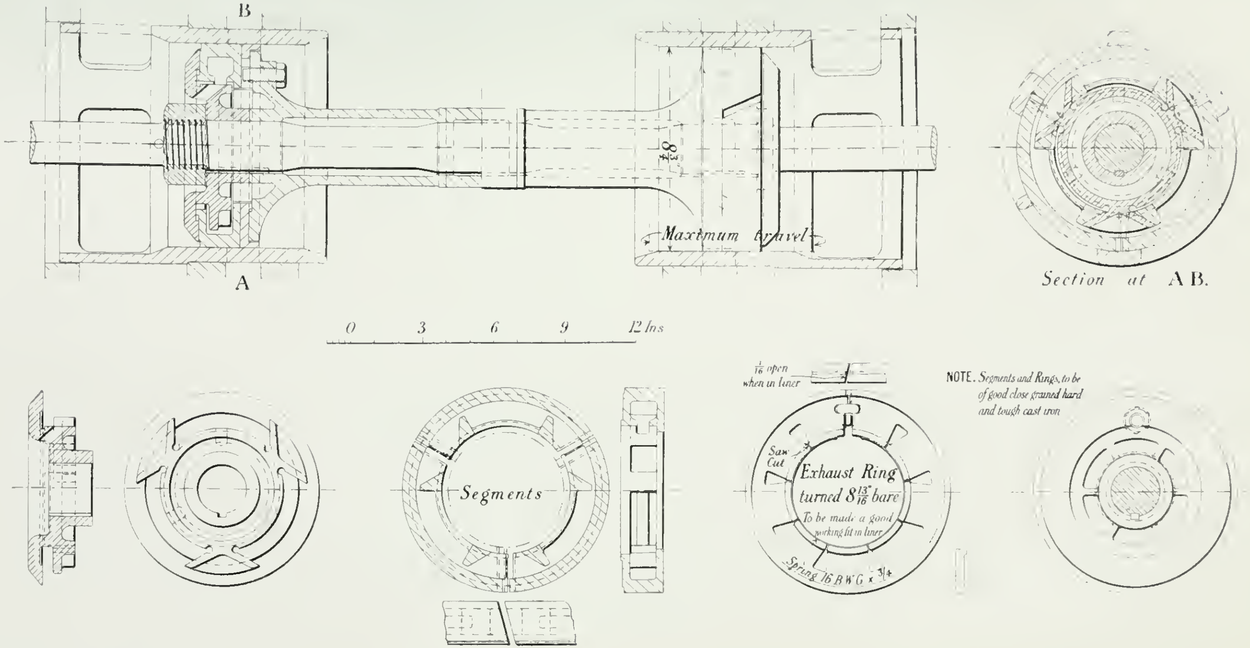
Mechanical Engineers 1902.

Scale $\frac{1}{8}$th.

Plate 63.

CYLINDRICAL VALVES FOR LOCOMOTIVES.

Fig. 15. $8\frac{3}{4}$"-Valve for H.P. Cyl., fitted to three Cyl. Compound, 1898.
(Photo, see Fig. 3, Plate 61. Details, Plates 65—68).



Mechanical Engineers 1902.

Scale $\frac{1}{8}$th.

Plate 64.

Cylinders, 19" × 26". (Engine, Fig. 3. Plate 61.)

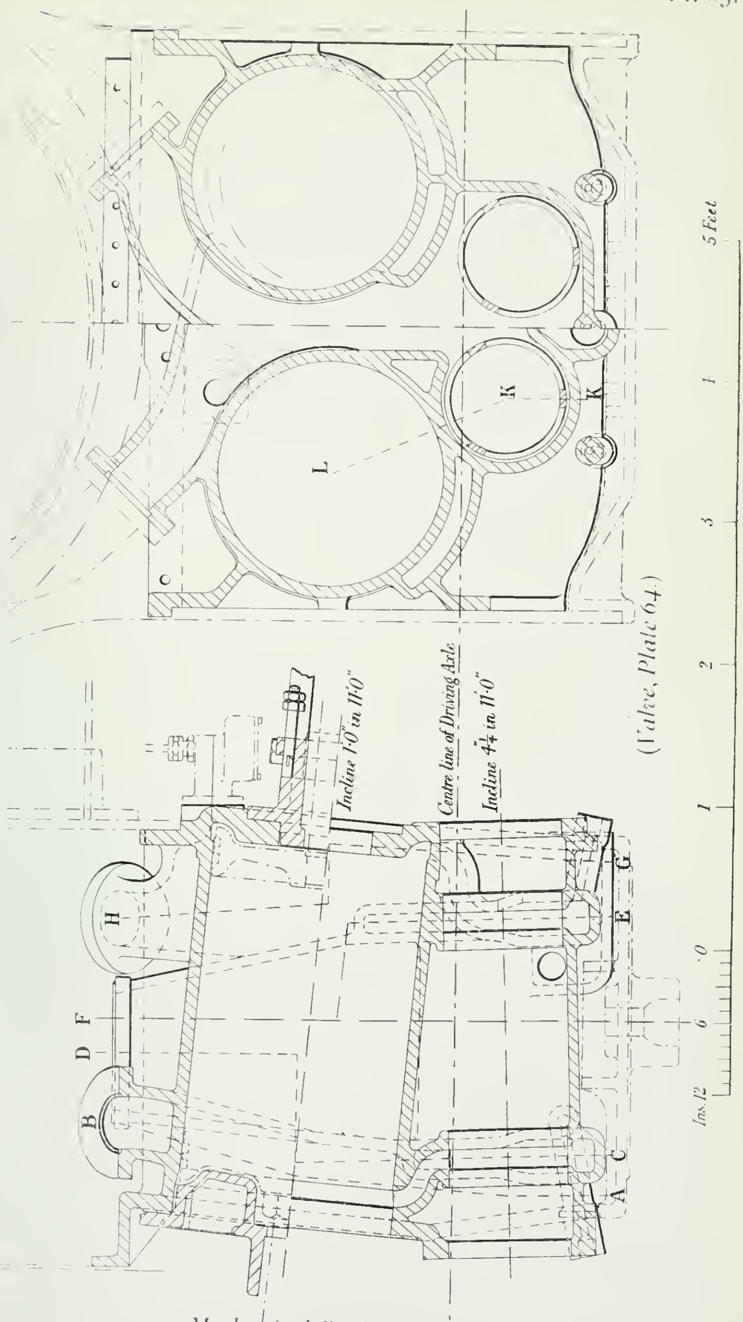


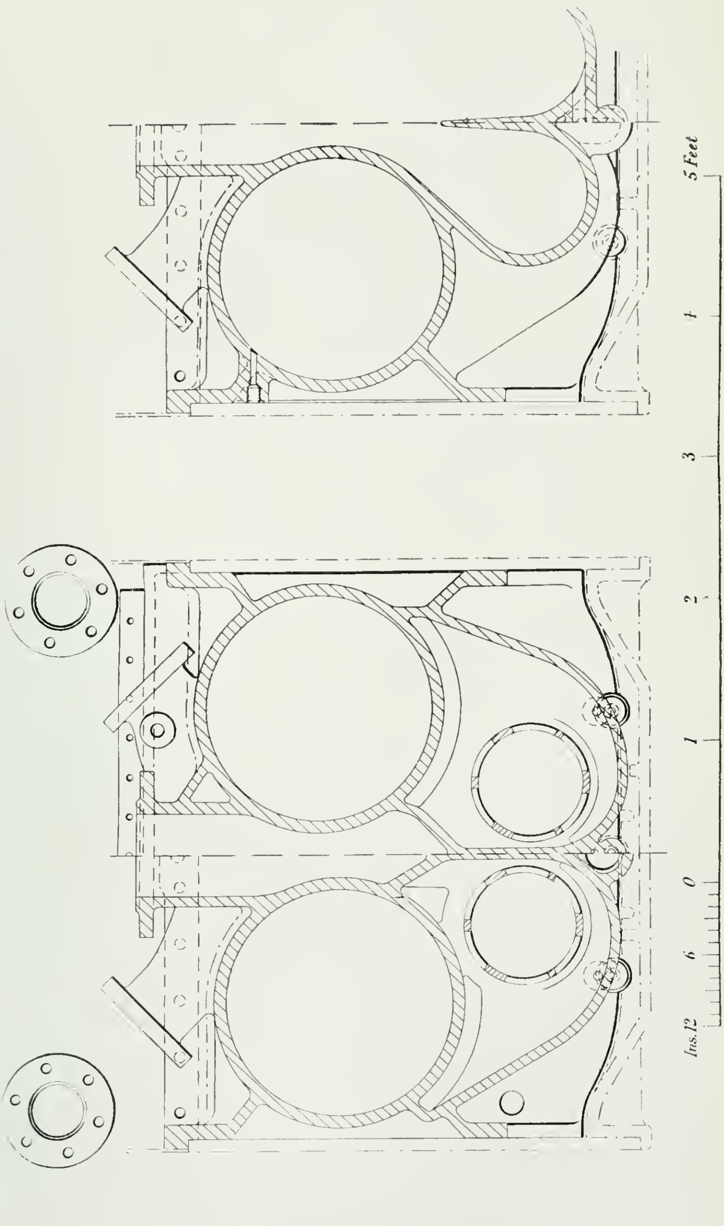
Fig. 18. *Section at K.L.*

Fig. 19. *Section at G.H.* *Section at A.B.*

(Valve, Plate 64.)

Fig. 20. Cylinders, 19" × 26". (Engine, Fig. 3, Plate 61.) Plate 66.

Section at E.F. (Fig. 18.) Section at C.D. (Fig. 18.) Fig. 21. Section through Exhaust.



CYLINDRICAL VALVES FOR LOCOMOTIVES.

Cylinders, 19" × 26". (Engine, Fig. 3, Plate 61.)

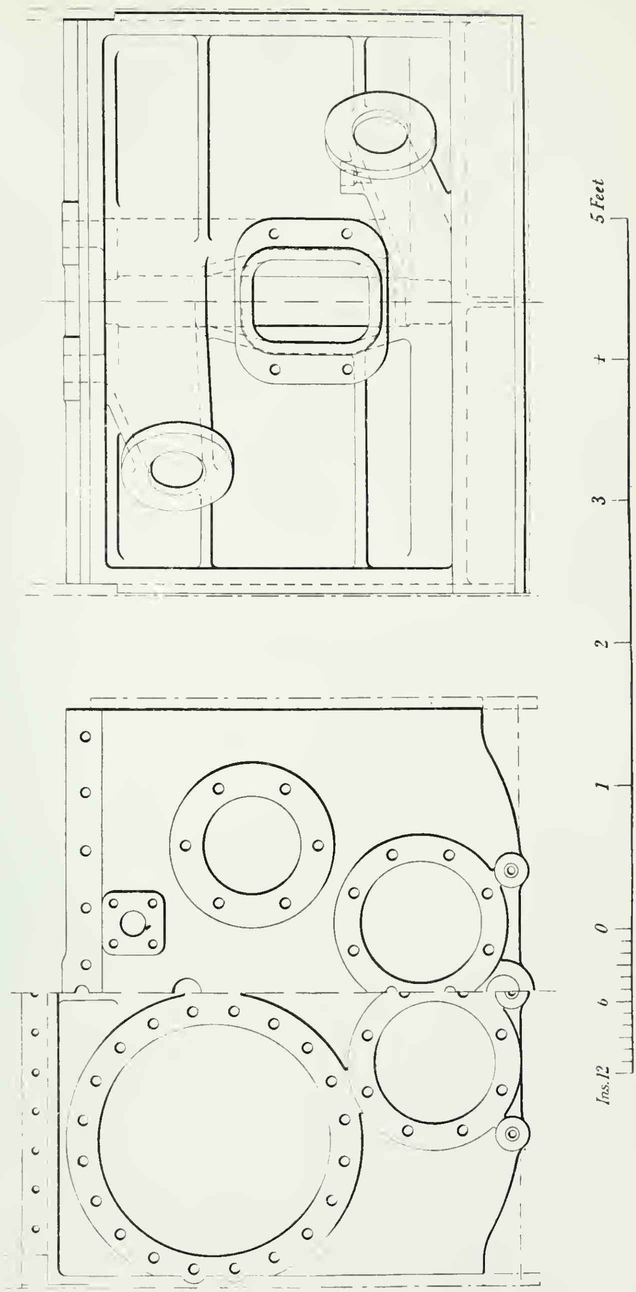


Fig. 22. Back view. Front view.

Fig. 23. Plan of top.

Plate 68.

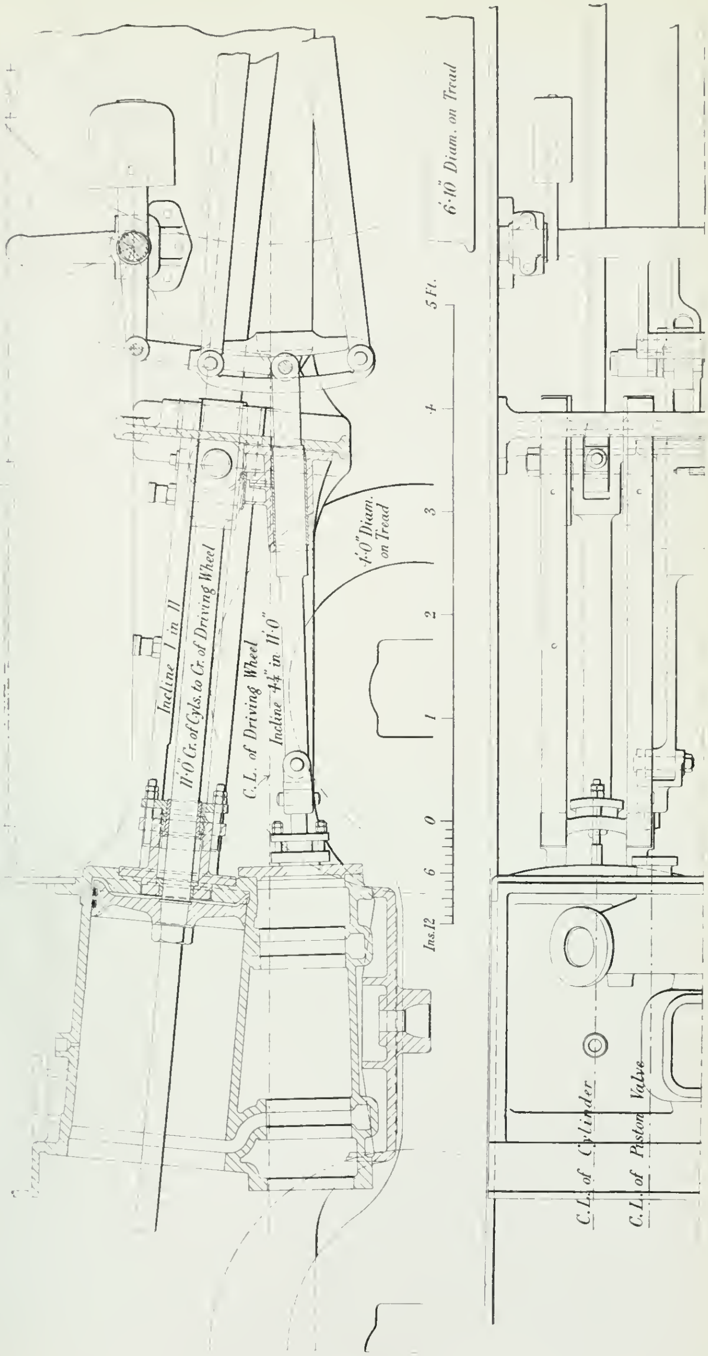


Fig. 24. *Valve Motion of Engine, Fig. 3, Plate 61. (Cylinders, Plates 65—67.)*

Fig. 26.
Automatic Air and Steam Admission-Valve.

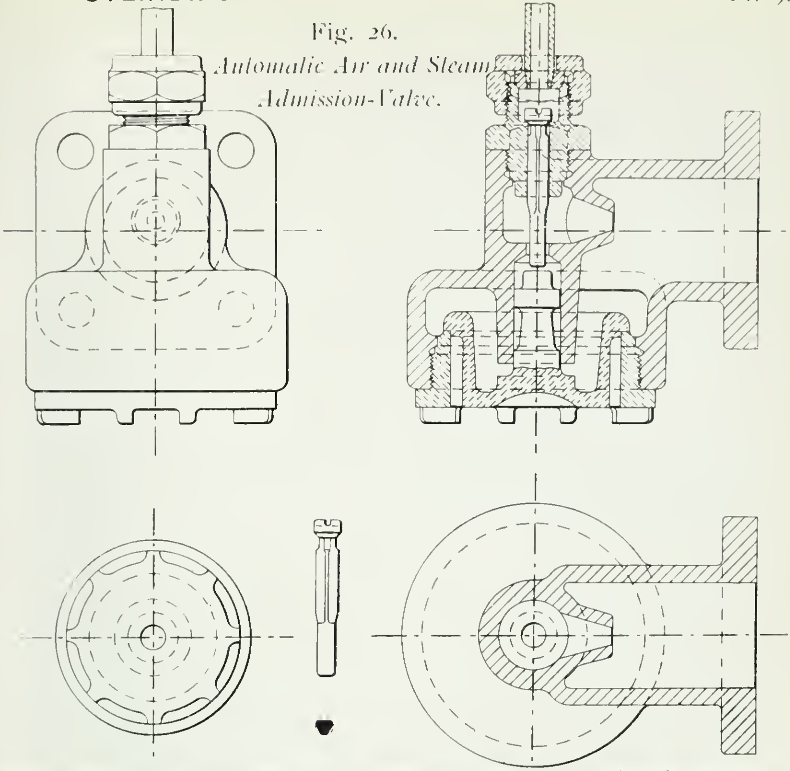
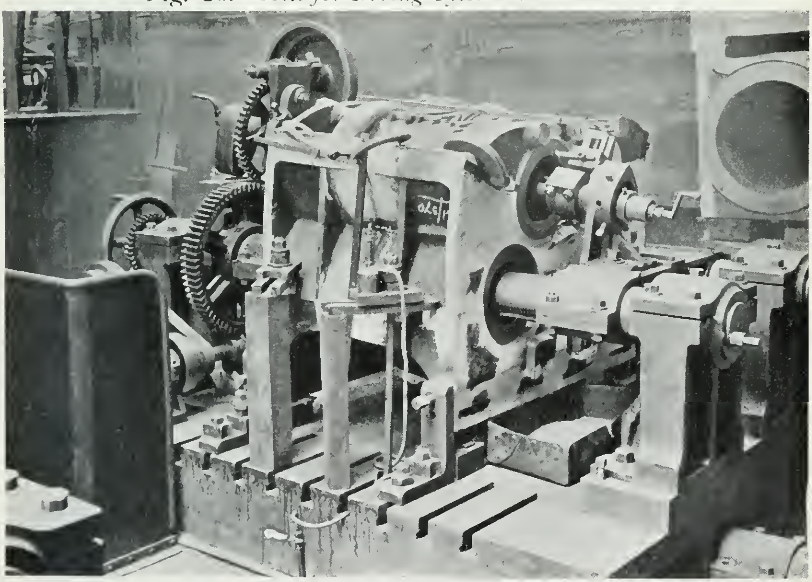


Fig. 28. *Mill for Boring Cyls. and Valve Chambers.*



Percussive Rock-Drill. (Frölich.) Plate 70.

Fig. 1. *Arrangement showing method of Holing for Coal.*

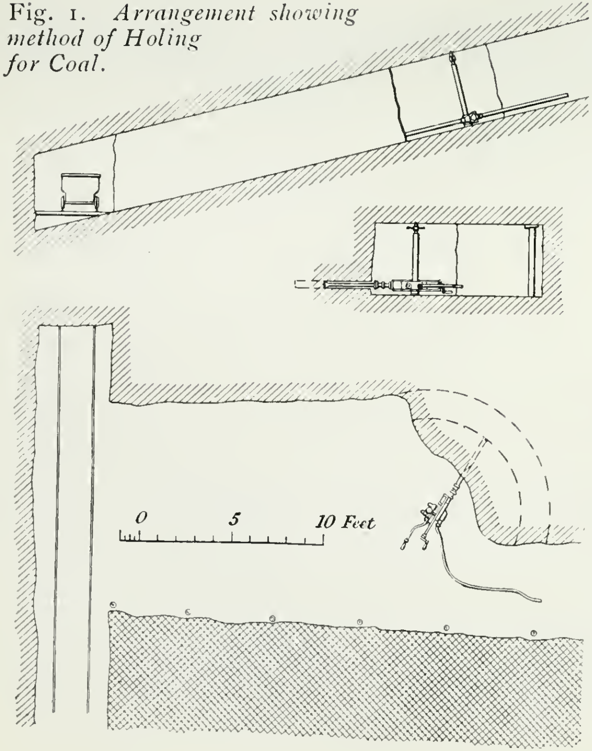
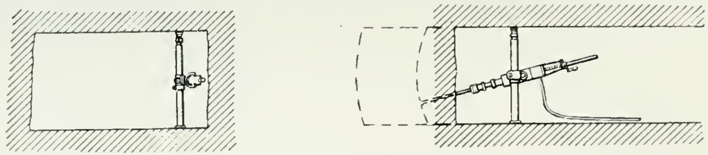


Fig. 2. *Arrangement showing method of using Machine for Heading.*



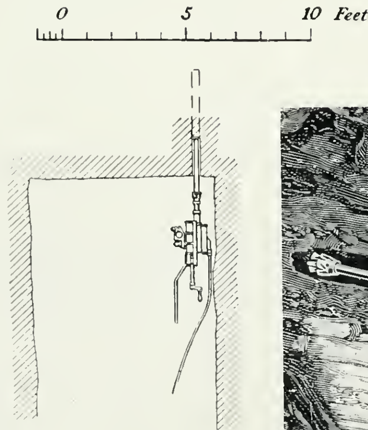
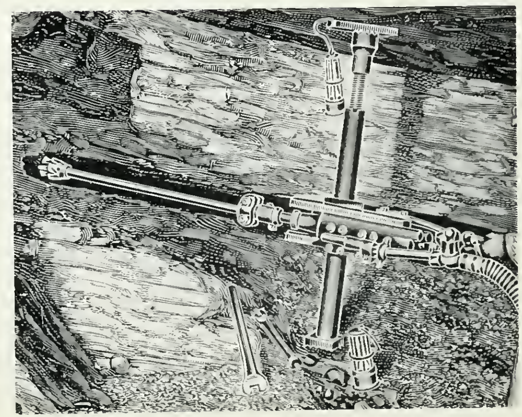


Fig. 3. *Working position.*



Mechanical Engineers 1902.

Percussive Rock-Drill. (Frölich.)

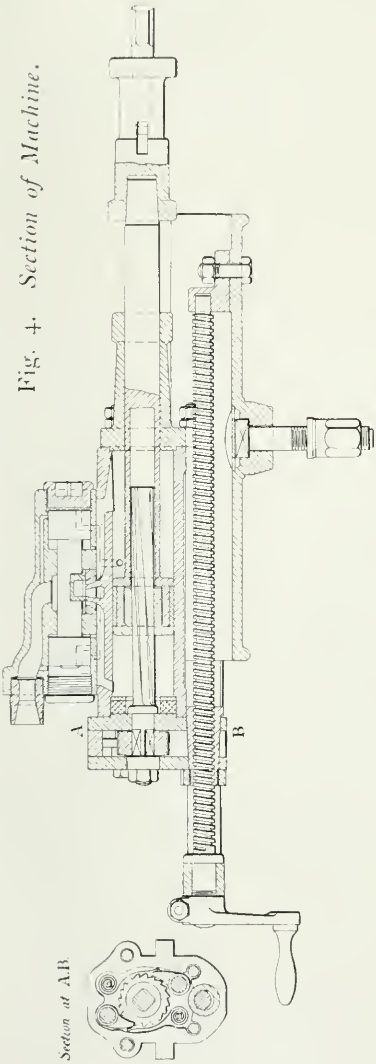


Fig. 4. Section of Machine.

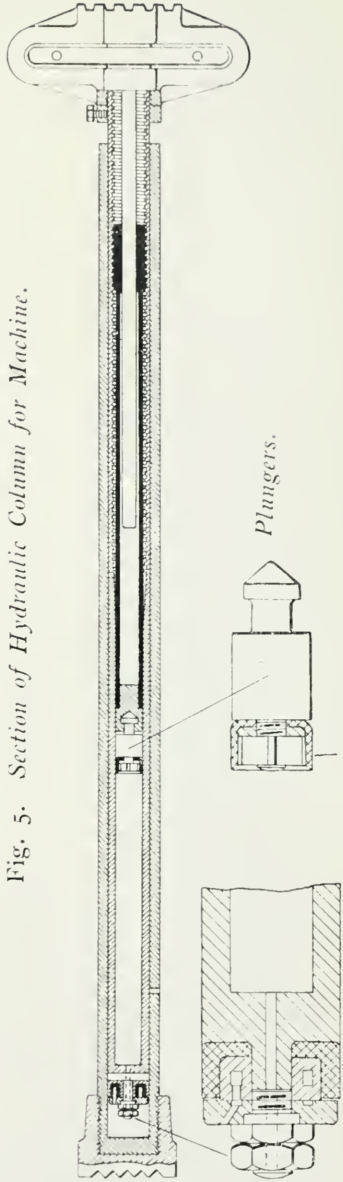
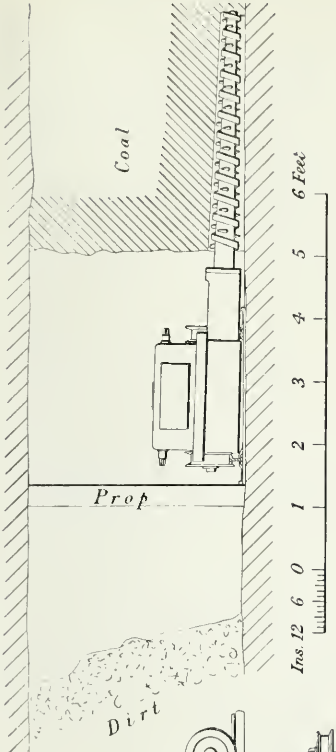
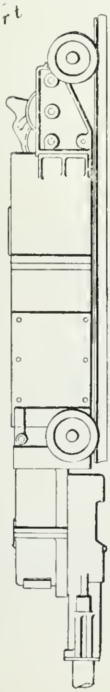


Fig. 5. Section of Hydraulic Column for Machine.

Bar-Type Coal-Cutter (Hurd.)





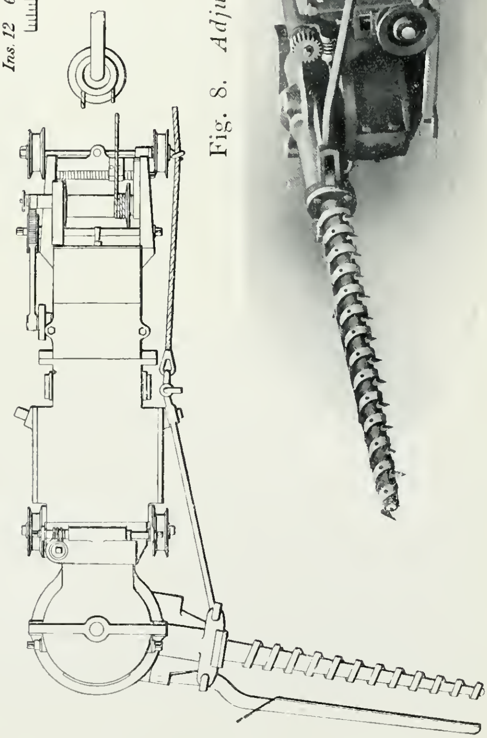


Fig. 7. Adjusted for Under-Cutting.

Fig. 9. Cutter Pick. ($\frac{1}{4}$-size.)

Fig. 8. Adjusted for Over-Cutting.

Fig. 10. *Coal-Cutting at Floor-Level.*
(Clarke-Stephenson.)

This machine is also made without the intermediate gear for cutting at higher level.

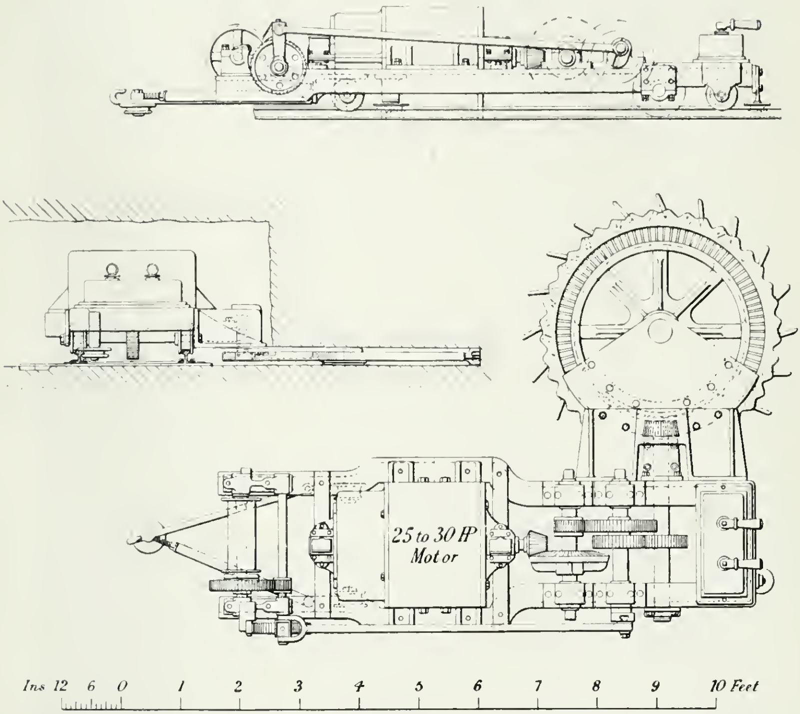
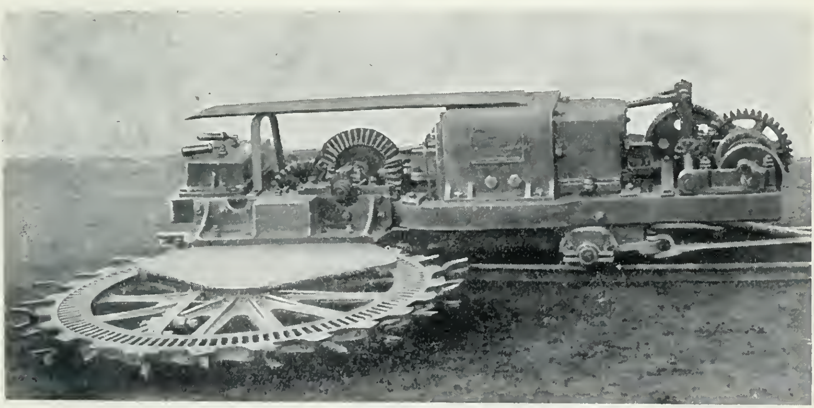


Fig. 11.



Mechanical Engineers 1902.

Fig. 12. *Undercut Electric Coal-Cutter.* (*Diamond Co.*)

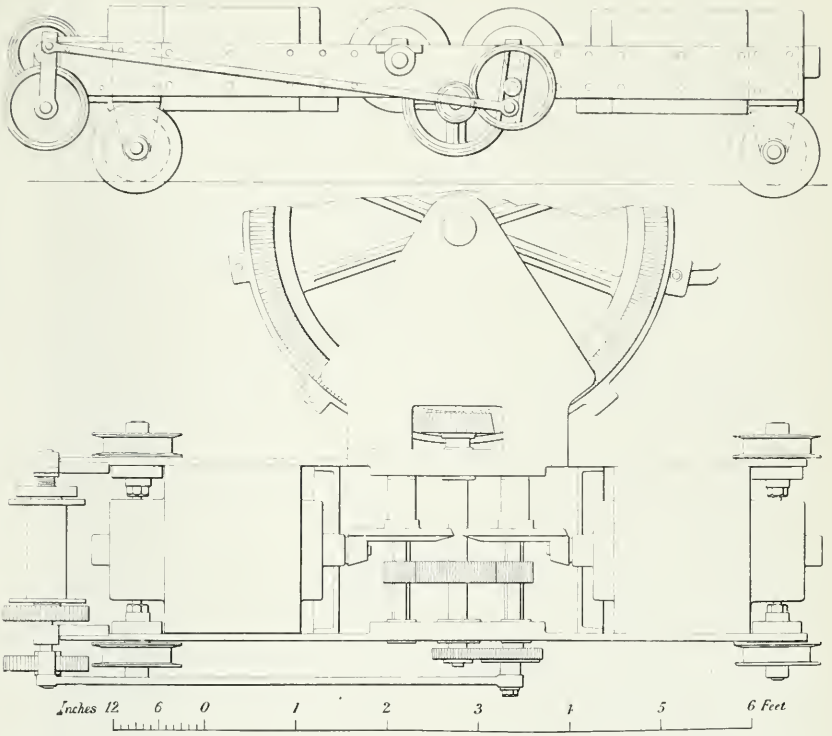
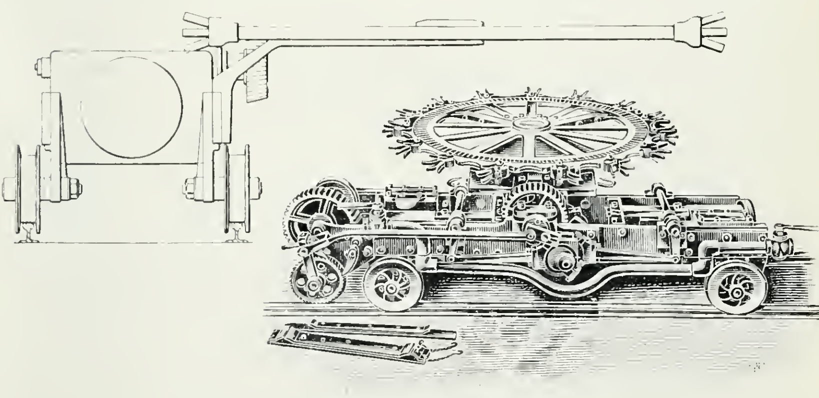


Fig. 13. *Overcut Electric Coal-Cutter.*

To cut 2 feet above floor-level. To hole 5 feet. (*Diamond Co.*)



Mechanical Engineers 1902.

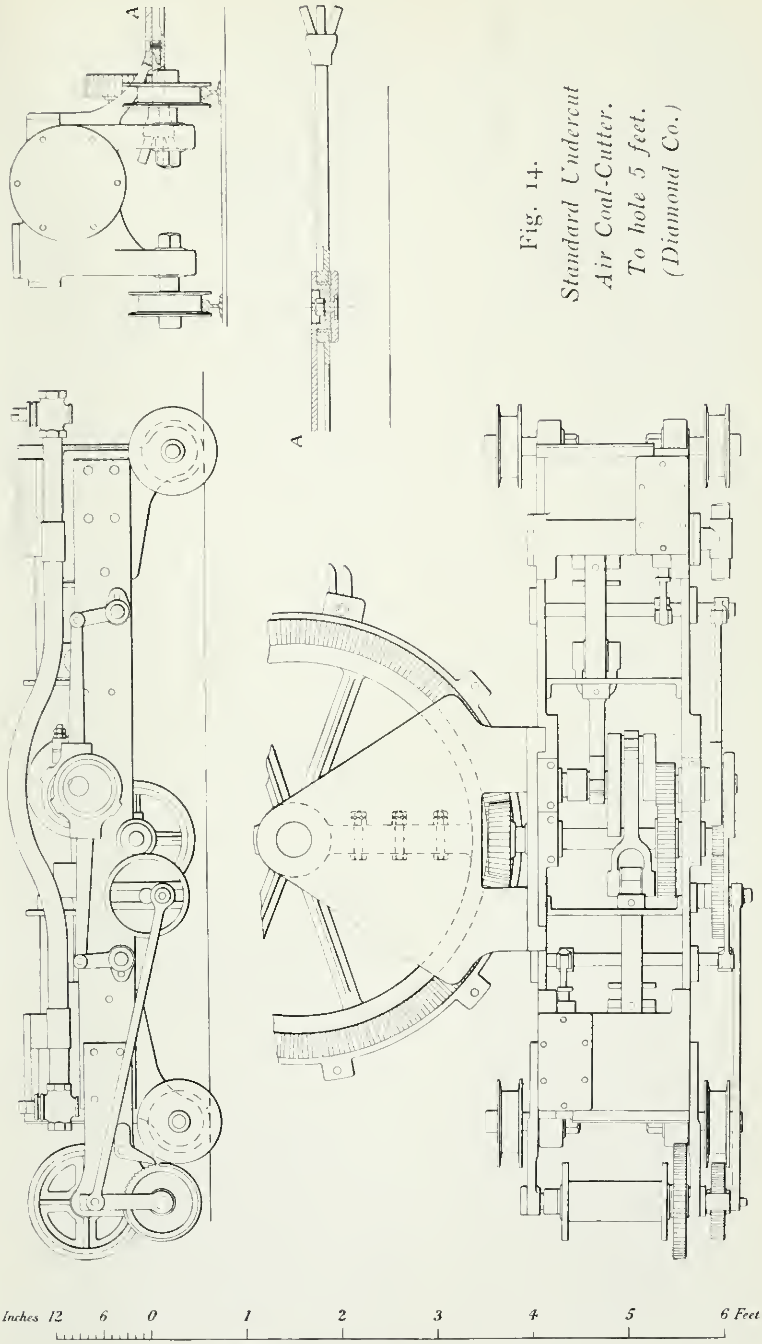


Fig. 14.
Standard Undercut Air Coal-Cutter.
To hole 5 feet.
(Diamond Co.)

MECHANICAL APPLIANCES IN MINES.

Chain Heading-Machine for Low Seams (Jeffrey).

Fig. 16. *Driven by Compressed Air.*

Fig. 17. *Driven by Electricity.*

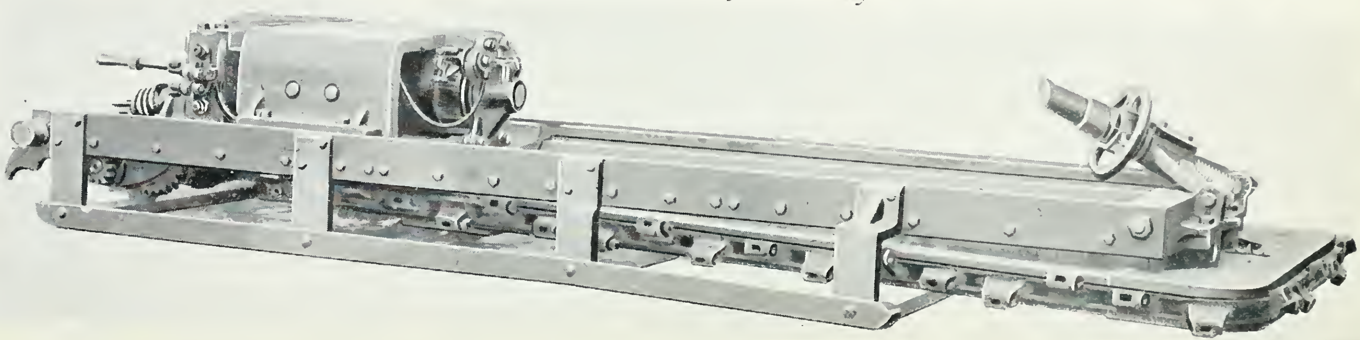
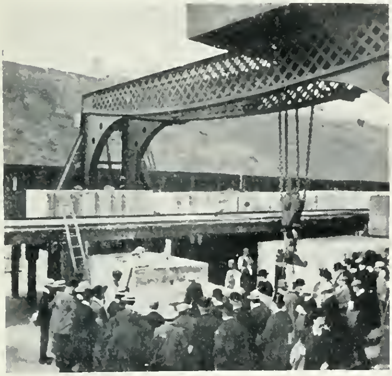


Plate 76.

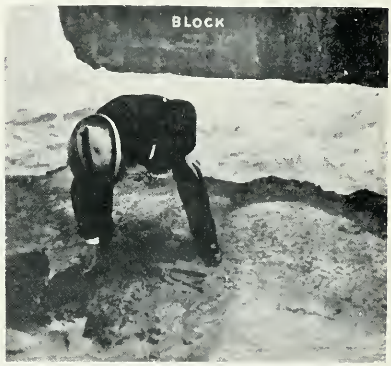
Laying a 45-ton Block at the end of Roker Pier, Sunderland, by the President, 31st July, 1902.

Setting Granite Stone.



Block slung in 60-ton Crane.

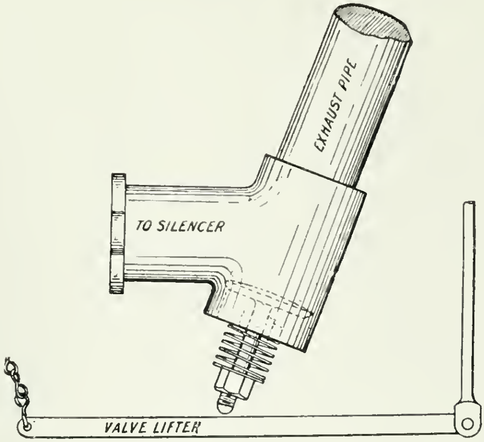
Spreading the Cement.



Setting the Block.

Crane and Sand Dredger at end of Pier.

Fig. 16. *Exhaust Release Valve (Brooke).*



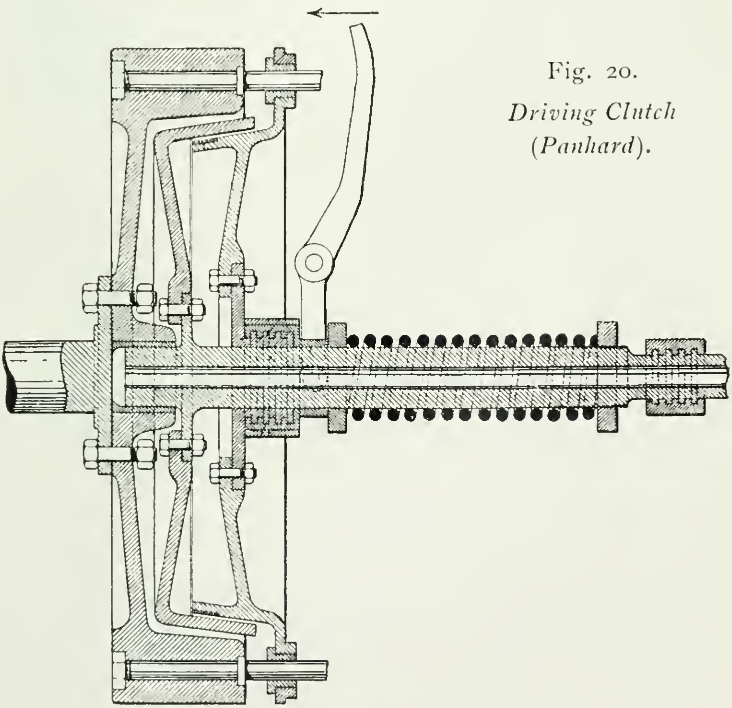


Fig. 20.
Driving Clutch (Panhard).

Fig. 22.

Driving Gear (Mors).

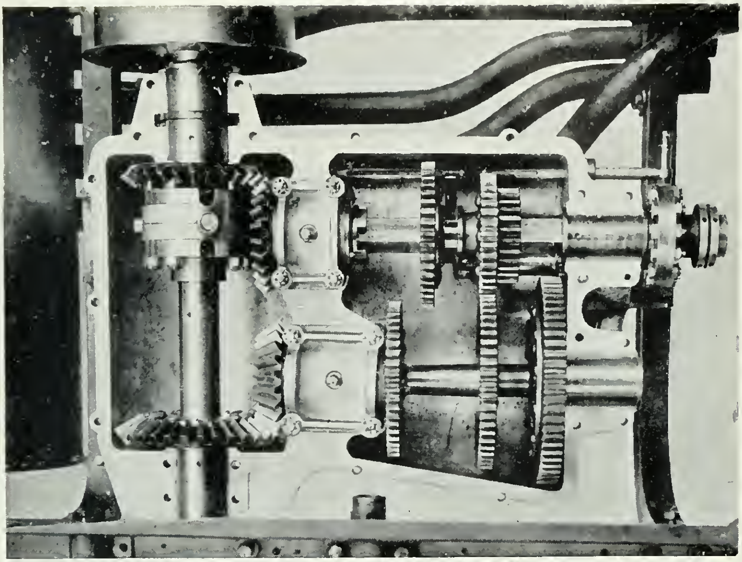
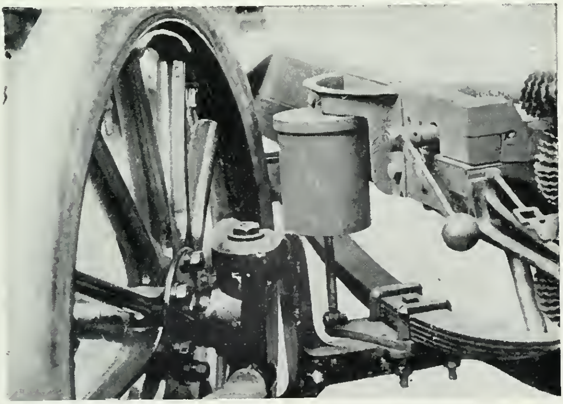


Fig. 26.

Pneumatic Buffer (Mors).



(Mr. Charles T. Crowden's exhibit)

Petrol-Cycle Motor (Butler).

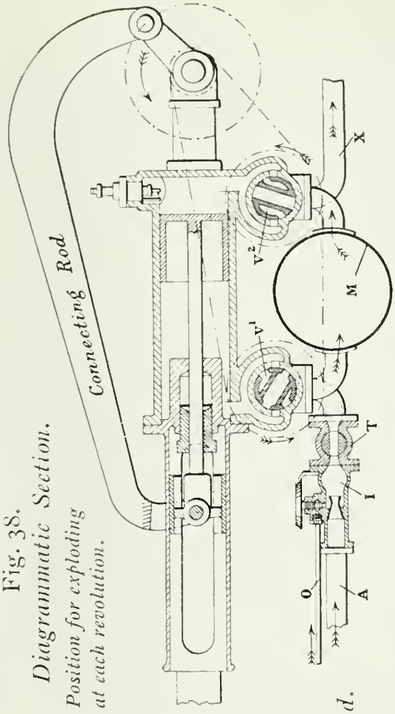


Fig. 38.
Diagrammatic Section.
Position for exploding at each revolution.

O. Oil Pipe from Cistern. V^2. Admission and Exhaust Valve.
I. Spray Inspirator. X. Exhaust to Silencer.
V^1. Rotative Inlet & Outlet Valve. A. Air Pipe from Dust Filter.
M. Compressed Mixture Chamber. T. Throttle Regulator.
Compression takes place at front end of piston.

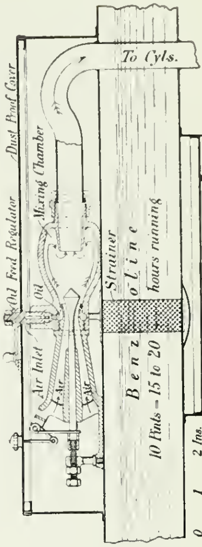


Fig. 40. Liquid Hydrocarbon Inspirator.

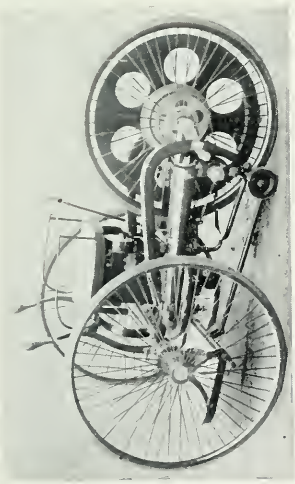


Fig. 37. Velocycle, 1886-87; Water Cooler removed.

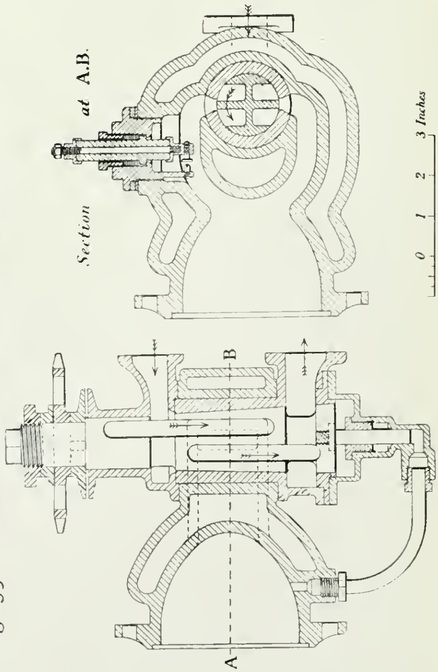


Fig. 39. Balanced Rotative Valve and Cylinder Head.

Hawaiian Commercial and Sugar Co., Kahului-Maui.

Fig. 1. General Arrangement of Factory Buildings with surrounding Services for Water and Transportation.

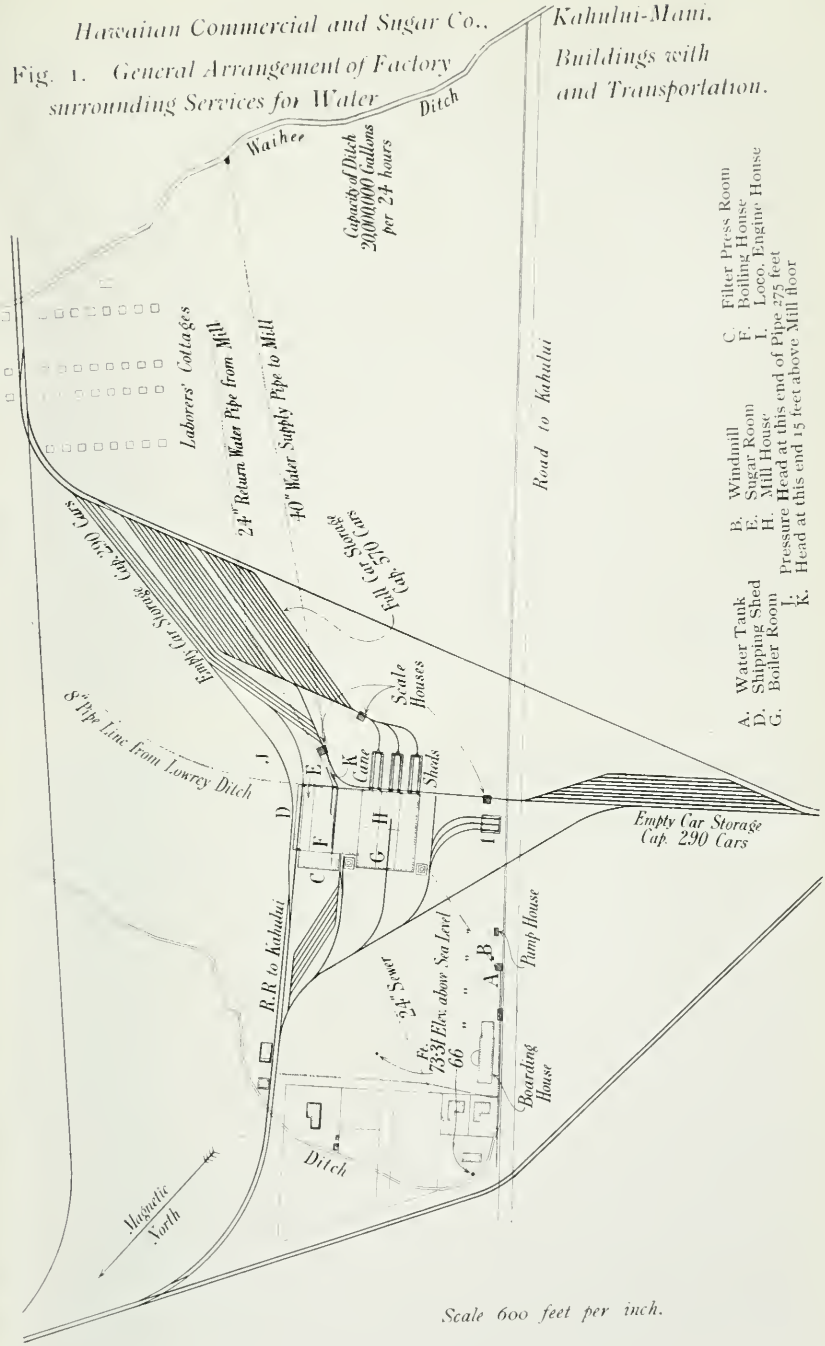


Fig. 2. *Outside of Factory, looking S.W.*

Fig. 3. *Cane Unloading Machine in operation.*

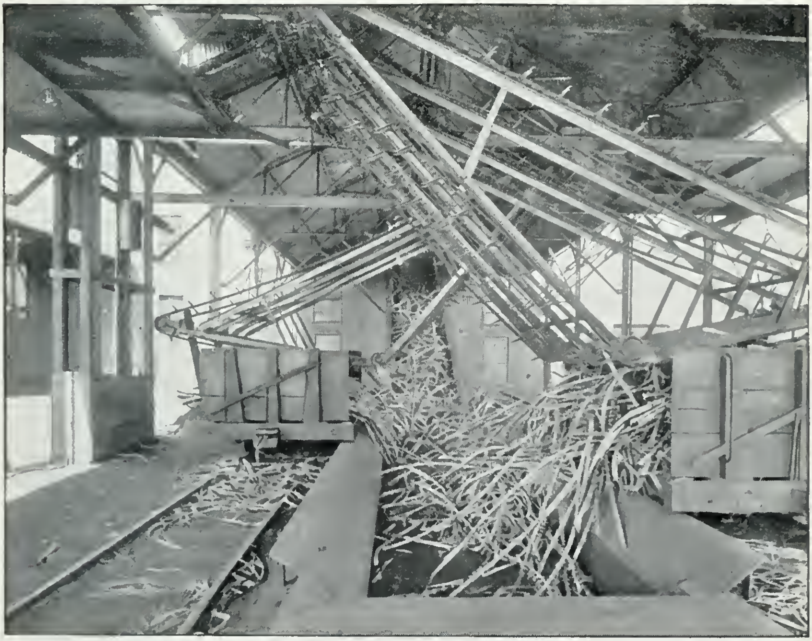
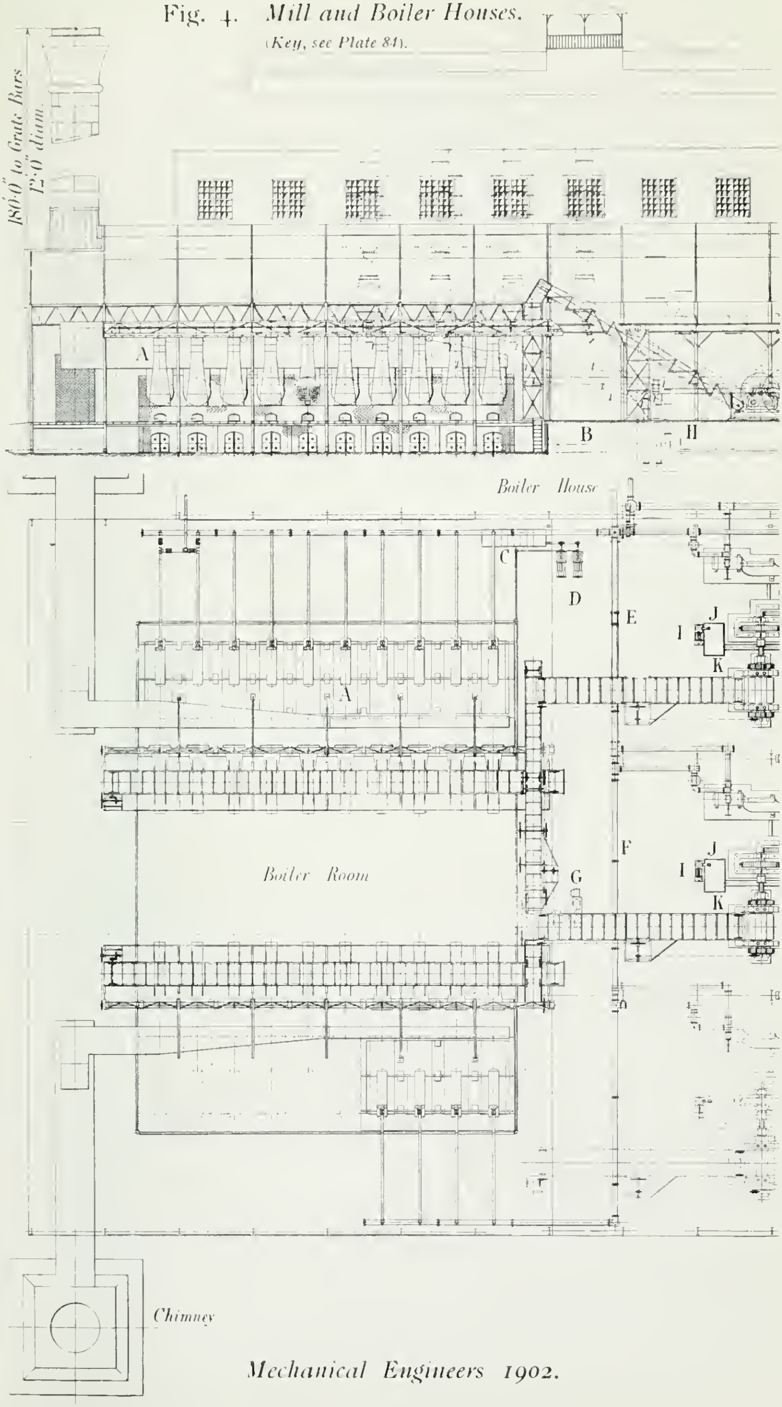


Fig. 4. *Mill and Boiler Houses.*

(*Key, see Plate 84*).



Continued on Plate 84.

Fig. 4. *Mill and Boiler Houses.*

(Key for Plates 83 and 84).

A. Boilers 7' 0" by 20' 0"
B. Sewer Pipe 2' 0"
C. Hot Well
D. Boiler Feed Pumps 10" & 5" by 10" Duplex
E. Exhaust Steam Pipe 1' 6"
F. Live Steam Pipe 1' 2"
G. Engine for Driving Bagasse Carriers 1' 0" by 1' 6"
H. Sealing Well
I. Juice Pump 6" & 8½" by 6"
J. Juice Tank
K. Juice Strainer
L. 15-ton Travelling Crane
M. Corliss Engine 2' 6" by 5' 0"
N. Nine-Roller Mill 2' 10" by 6' 6"
O. Krajewski Crusher 2' 2" by 6' 0"
P. Hydraulic Accumulators and Pumps
Q. Water Supply Pipe 3' 4"
R. Cane Carrier

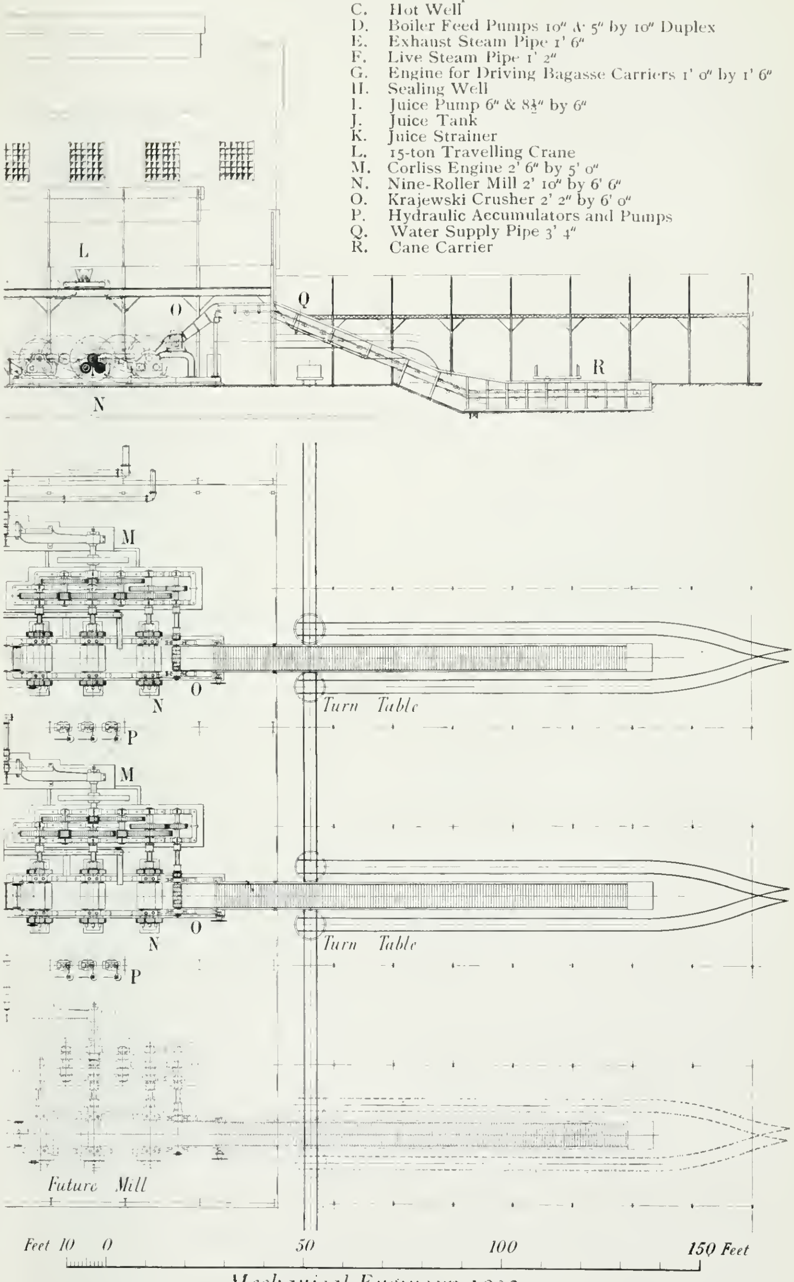
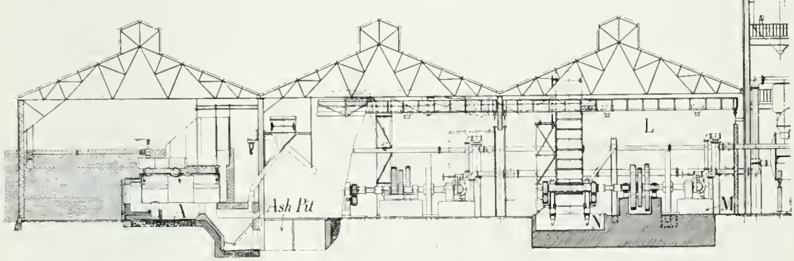


Fig. 5. *Mill, Boiler, Concentrating and Finishing Houses.*

(*Key for Plates 85 and 86*).

A. Boilers 7' 0" by 20' 0"
L. 15-ton Travelling Crane.
M. Corliss Engine 2' 6" by 5' 0"
N. Nine Roller Mill 2' 10" by 6' 6"
1. Juice Weighers
2. Liming Tanks
3. Mud Tanks below
4. Settling Tanks
5. Sand Filters
6. Hot Water Tank
7. Vacuum Pumps 16" & 24" by 9"
8. Juice Pumps 7½" & 8½ by 10"
9. Lillie Evaporators
10. Exhaust Steam Pipe 1' 6"
11. Live Steam Pipe 1' 0"
12. 50-Kw. Generator for Electric Lighting
13. Lime Room
14. Superheating Apparatus
15. Air Compressor on 1st Floor 1' 0" by 1' 6"
16. Vacuum Pumps for Vacuum Pans on 1st Floor 16" & 22" by 24"
17. Pumps for driving Centrifugals on 1st Floor 22" & 12" by 24"
18. Passenger Elevator
19. Water Supply Pipe 3' 4" from Waihee Ditch
20. Return Water Pipe 2' 0" to Waihee Ditch
21. Stairs to Observatory
22. Filter Presses
23 Chemical Laboratory
24. Engineers' Office
25. Engine for driving Crystallizers on 1st floor 1' 8" by 4' 0"
26. Future Vacuum Pan
27. Vacuum Pans
28. Crystallizers
29 16 Water-Driven Centrifugals 3' 4"
30. Bagging Bin
31. Tanks for Syrup
32. Syrup Weigher
33. Supply Tanks for Vacuum Pans
34. Tanks for 1st Molasses
35. Tanks for 2nd Molasses
36. Mixer
37. Molasses Blow-up Tank
38. Sealing Well



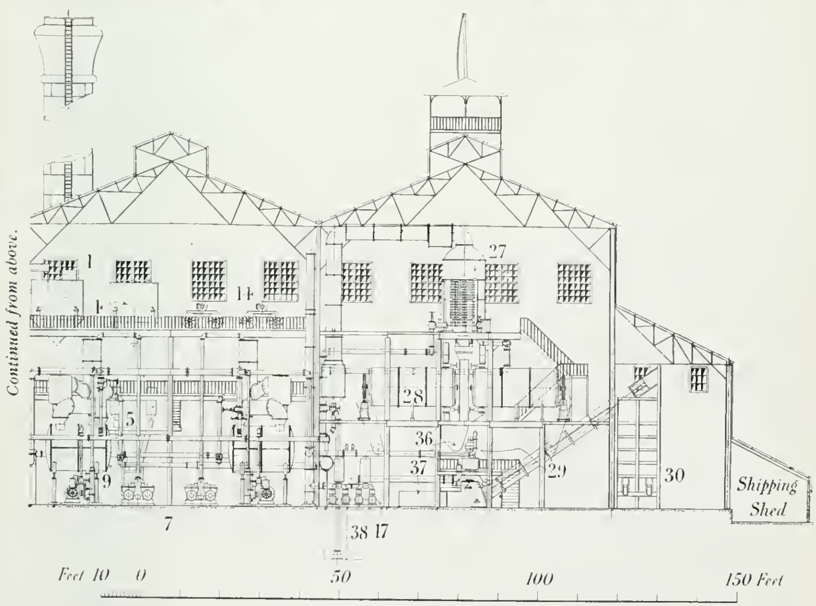


Fig. 6. Concentrating and Finishing House.

(Key, see Plate 85).

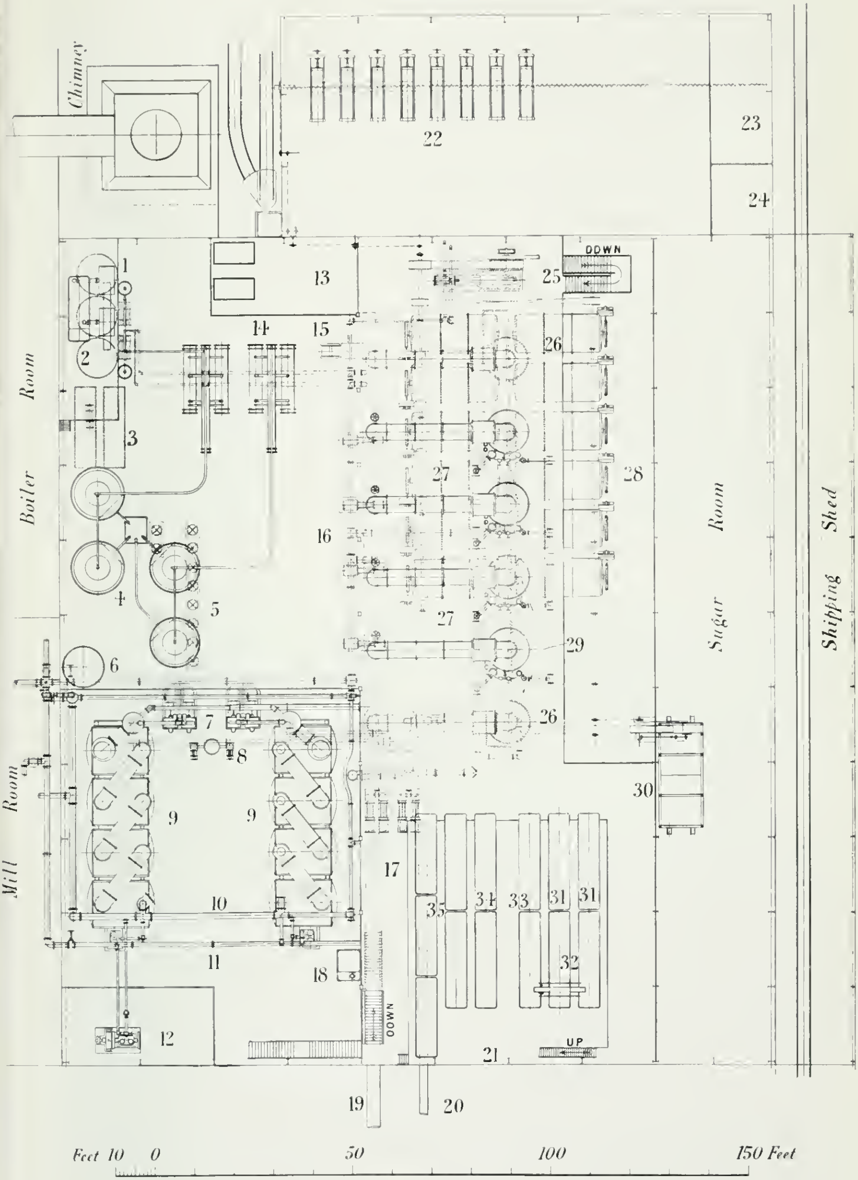
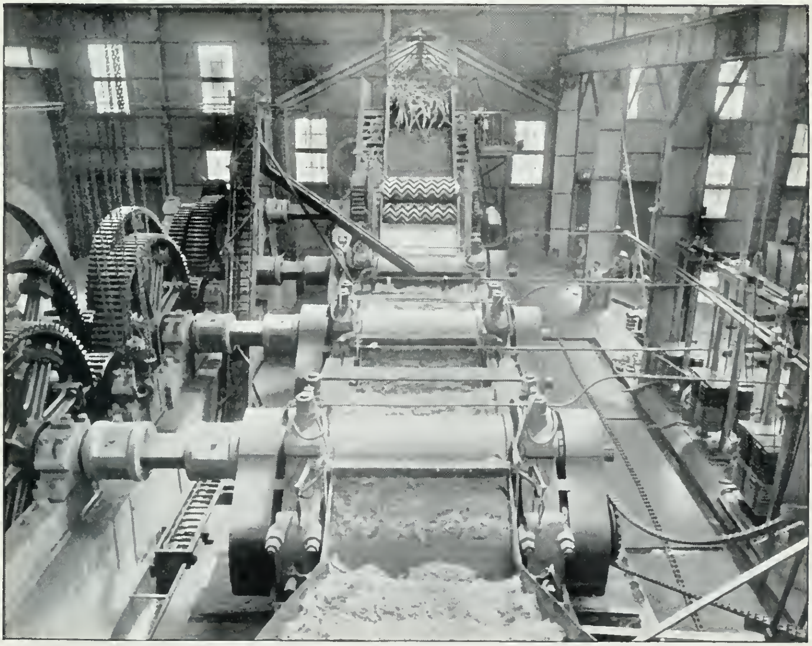


Fig. 7. *Engine and Gearing for Crushing Mill.*

Fig. 8. *Nine-Roller Crushing Mill.*



Mechanical Engineers 1902.

Fig. 9. *Automatic Firing Mechanism, with surplus bagasse on floor in front of boilers.*

Fig. 10. *Sugar Room showing Vacuum Pans and Crystallizers.*

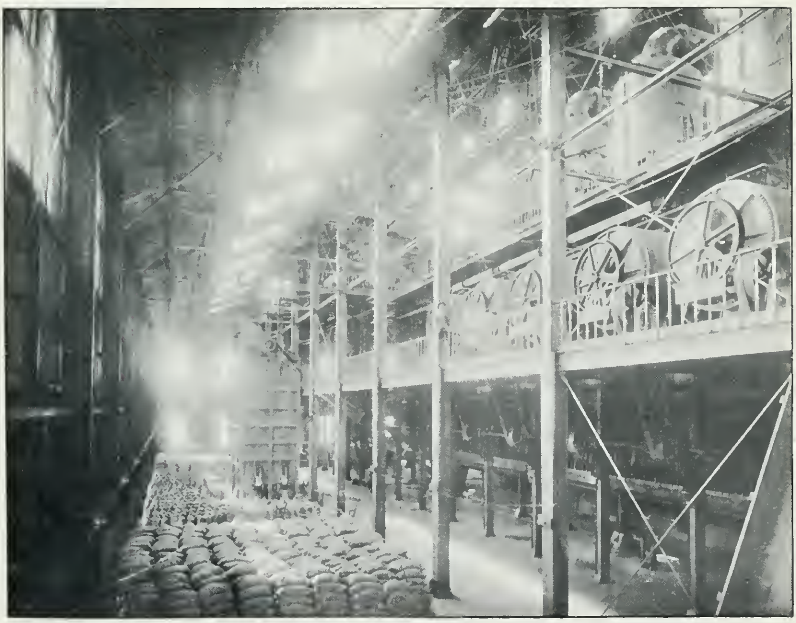
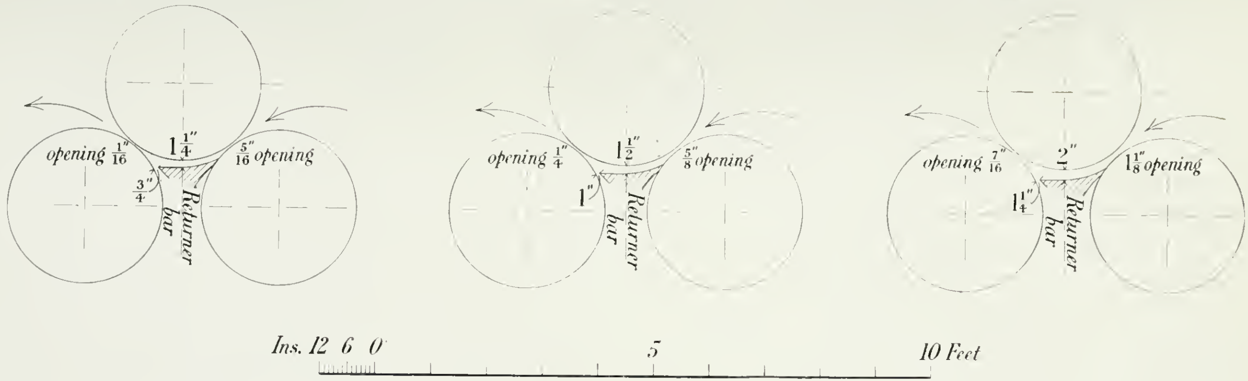


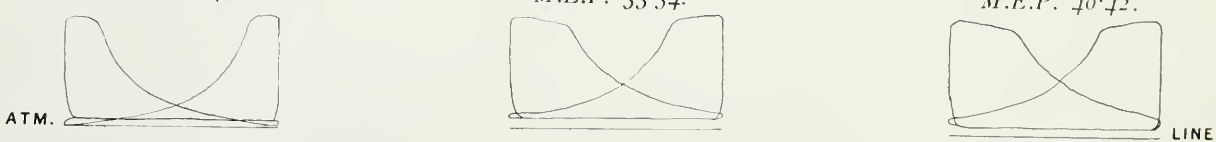
Plate 89.

Fig. 11. *Nine-Roller Crushing Mill. Setting of Cane Returner Bars.*

(For Plan of Mill see Plate 84, and for Detail of Returner Bar see Fig. 19, Plate 92.)

No. 3. *Mill, 400 tons.* No. 2. *Mill, 320 tons.* No. 1. *Mill, 230 tons.*





Diagrams, showing variation in Power developed by this Mill Engine when griding at the rate of 50 tons of Cane per hour.

Dia. of Cyl., 2'·6". Stroke of Piston, 5'·0". Dia. of Piston-rod, 5". Scale of Ind. Spring, 140. Boiler Pressure, 83 lbs. Revs. per min., 48. Max. H.P., 410·95. Min. H.P., 207·6. Average H.P., 319·86.

Plate 90.

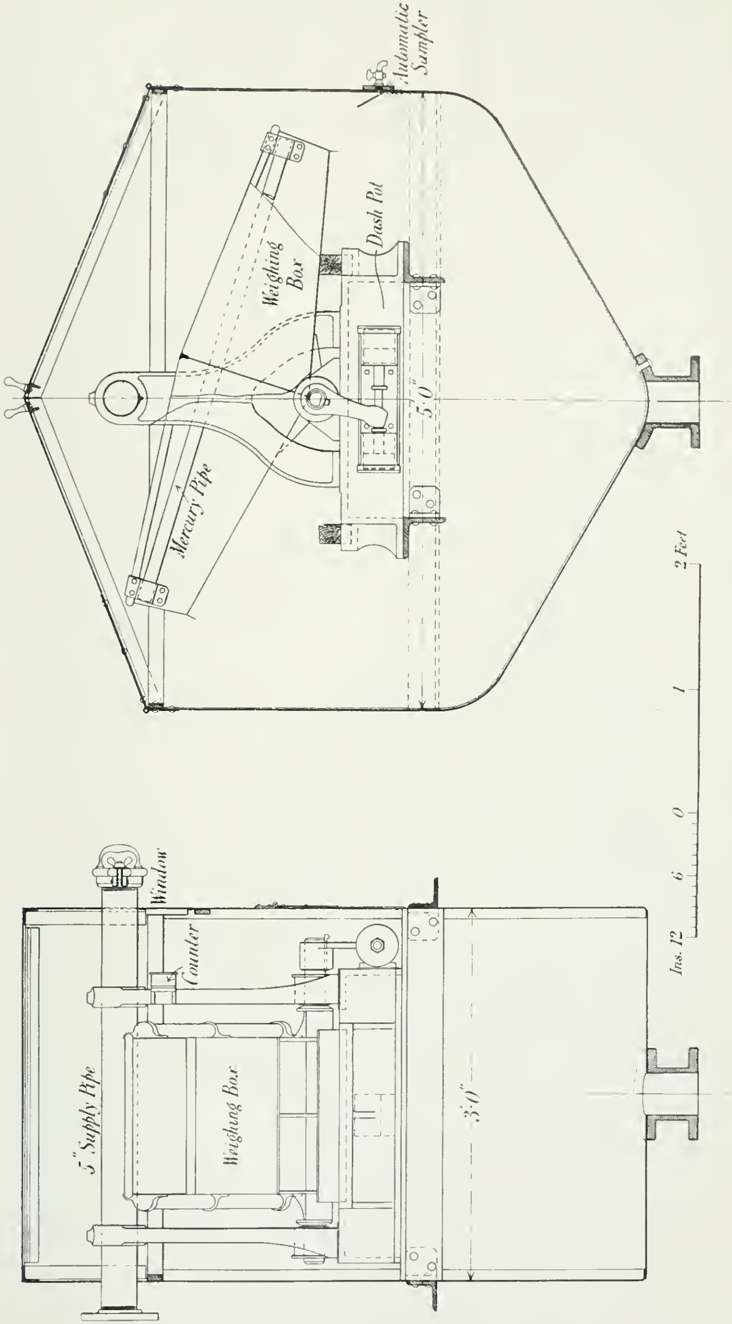


Fig. 12. *Automatic Weighing Machine for Juice and Molasses.*

Mechanical Engineers 1902.

Fig. 14. *Arrangement of Vacuum Pan.*

(Mr. Robert Graham's communication.)

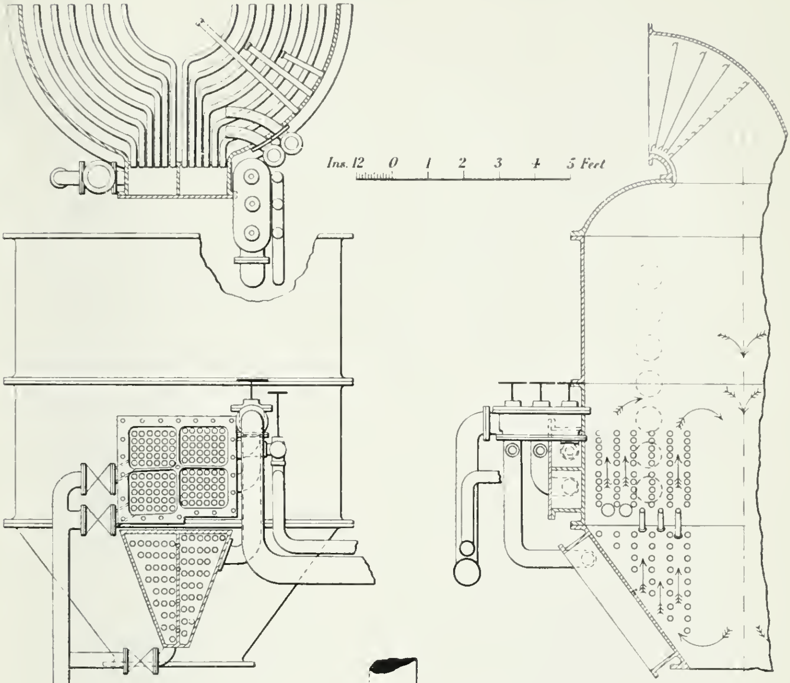


Fig. 18. *Sketch of Centrifugal showing construction of Basket.*

(Author's reply)

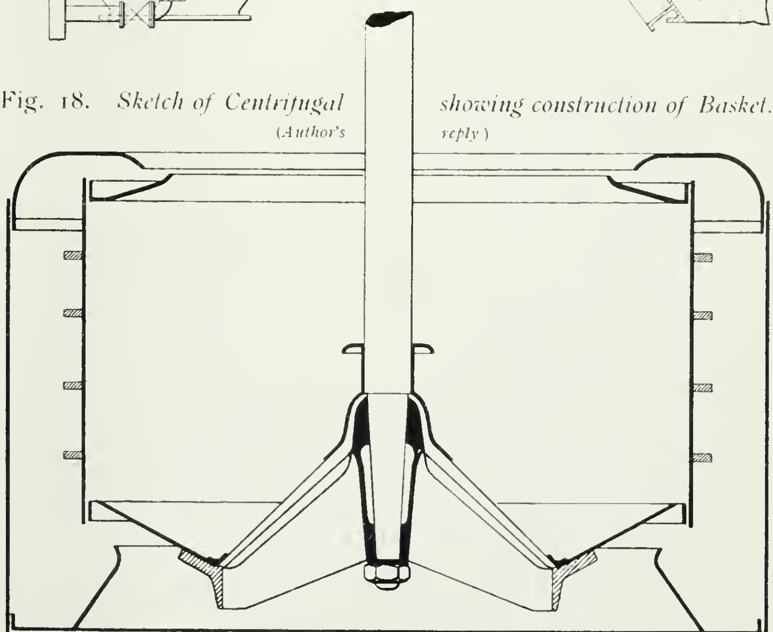


Fig. 19. Setting of Returner Bar. Nine-Roller Mill. 2nd. Set of Rollers. (See Plate 89.)

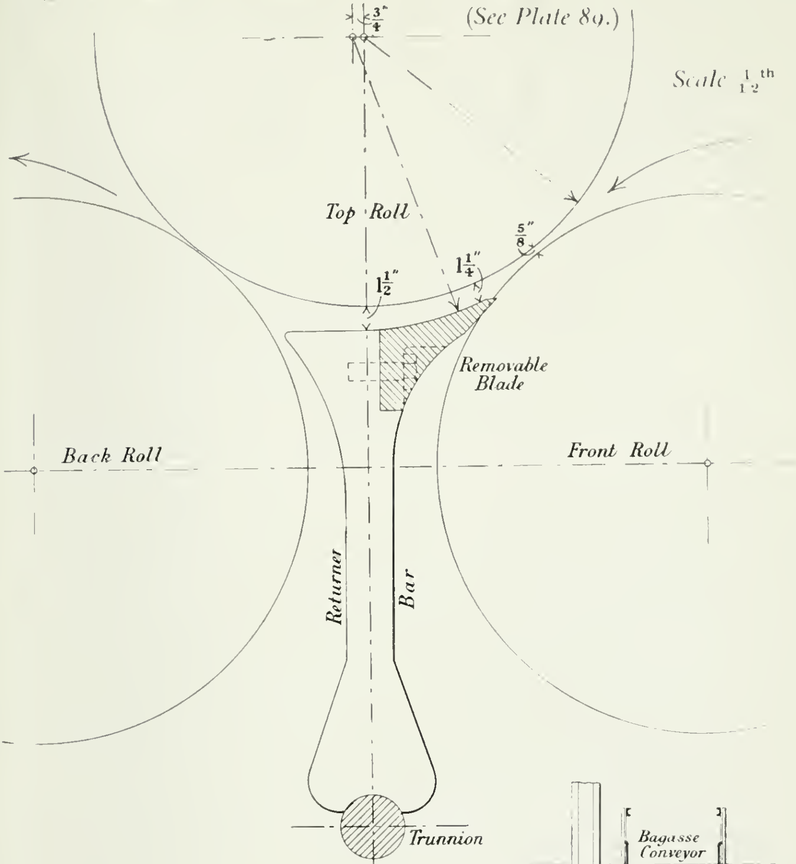
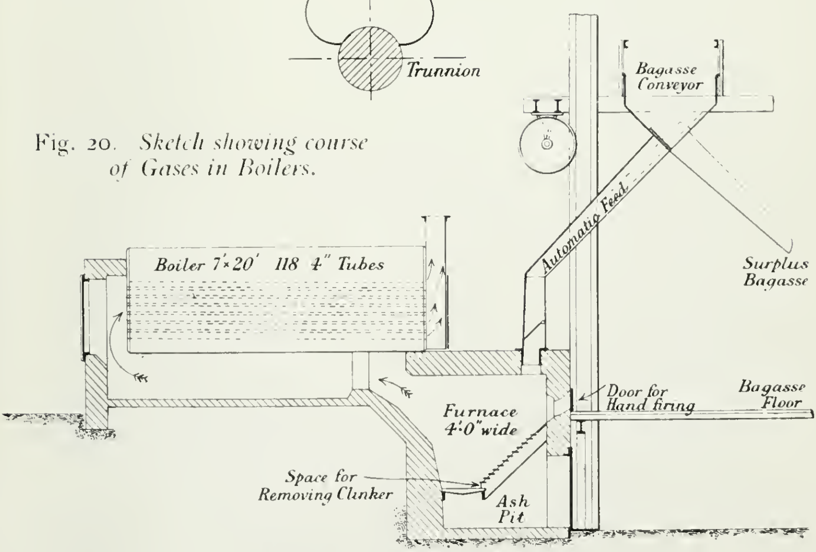
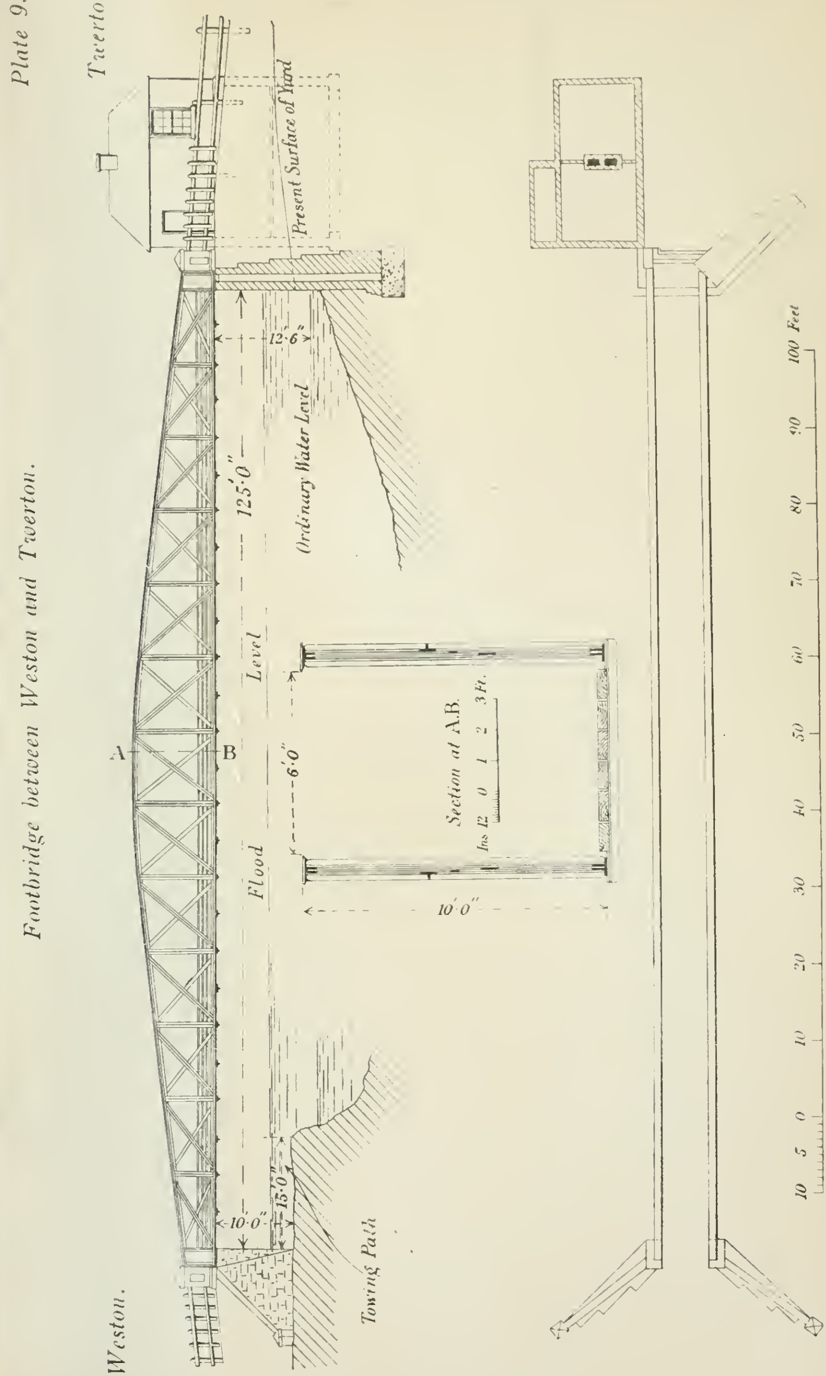


Fig. 20. Sketch showing course of Gases in Boilers.



WESTON TWERTON BRIDGE. *Plate 93.*



Mechanical Engineers 1902.

Institution of Mechanical
Engineers, London
Proceedings